PENNSYLVANIA GEOLOGICAL SURVEY
PUBLICATIONS SECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS

SUBSURFACE TRENTON AND SUB-TRENTON ROCKS IN OHIO, NEW YORK, PENNSYLVANIA AND WEST VIRGINIA

By
CHARLES R. FETTKE

TOPOGRAPHIC AND GEOLOGIC SURVEY
BULLETIN G 21
1948

PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES

BULLETIN G 21

SUBSURFACE TRENTON AND SUB-TRENTON ROCKS IN OHIO, NEW YORK, PENNSYLVANIA AND WEST VIRGINIA

By
CHARLES R. FETTKE

Reprinted from
BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 32, NO. 8, PP. 1457-1492

DEPARTMENT OF INTERNAL AFFAIRS
WILLIAM S. LIVENGOOD, JR., *Secretary*

TOPOGRAPHIC AND GEOLOGIC SURVEY
S. H. CATHCART, *Director*

1948

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/subsurfacetrento00fett

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 32, NO. 8 (AUGUST, 1948), PP. 1457-1492, 7 FIGS.

SUBSURFACE TRENTON AND SUB-TRENTON ROCKS IN OHIO, NEW YORK, PENNSYLVANIA, AND WEST VIRGINIA[1]

CHARLES R. FETTKE[2]
Pittsburgh, Pennsylvania

ABSTRACT

Exploration of Trenton and sub-Trenton rocks in the northern part of the Appalachian basin has been confined mainly to the shallower parts across central Ohio, southwestern Ontario, and western and central New York. Only a few wells have penetrated these rocks in the deeper parts of the basin. The salient features that have been revealed by the drilling are presented and discussed.

Maps showing the regional structure on the top of the Trenton limestone and the thicknesses of the Middle and the Upper Ordovician series in the northern part of the basin have been prepared. The lithologic characteristics of the Trenton and sub-Trenton formation across the northern part of the basin are described in six well-sample records. Their development underneath the area is shown by four series of stratigraphic sections based on well-sample records and drillers' logs.

Data are presented indicating that the dolomitic sandstones and sandy dolomites underlying the pre-Black River unconformity in central and northeastern Ohio and northwestern Pennsylvania, heretofore correlated with the St. Peter sandstone, do not represent a single geologic horizon but become progressively younger in a southerly direction in central Ohio.

Possibilities of the Trenton and sub-Trenton formations as potential sources of oil and gas are discussed.

INTRODUCTION

Trenton and sub-Trenton rocks underlie the strata from which the oil and gas of the Appalachian province have been produced. They constitute the lower part of the sedimentary section that overlies the pre-Cambrian in the Appalachian basin. Although the quantities of oil and gas that have been obtained from this part of the section in the Appalachian basin to date have been almost negligible, rocks of similar age have been prolific producers of both oil and gas in adjacent areas as well as other parts of the United States. Oil and gas reserves in the higher strata of the Appalachian province are dwindling rapidly and unexplored areas in them in which new discoveries of significant size may be expected are definitely limited. The time has come when the potentialities of the deeper strata need to be explored.

In the present paper the writer has brought together the salient features that have been revealed by deep exploration in central and eastern Ohio, southwestern and south-central New York, western Pennsylvania, and northwestern West Virginia. The area covered includes a large part of the northwestern flank of the Appalachian basin. Most of the exploration in Trenton and deeper strata

[1] Manuscript received, February 28, 1948. Published by permission of the director of the Pennsylvania Bureau of Topographic and Geologic Survey.

[2] Professor of geology, Carnegie Institute of Technology. Co-operating geologist, Pennsylvania Topographic and Geologic Survey. In connection with the preparation of the paper, the writer wishes to thank the individuals and companies who furnished the samples, well records, and other data on which the study is based. He is particularly indebted to Kenneth Cottingham of the Ohio Fuel Gas Company who provided well elevations, drillers' logs and a map showing locations of Trenton and sub-Trenton wells in central and eastern Ohio; and Robert G. Kurz and George T. Thomas of the Ohio Oil Company who made available their company's file of drillers' logs and several excellent sets of drill-cutting samples. The work on which the paper is based was done in connection with subsurface studies that the writer is making for the Pennsylvania Topographic and Geologic Survey.

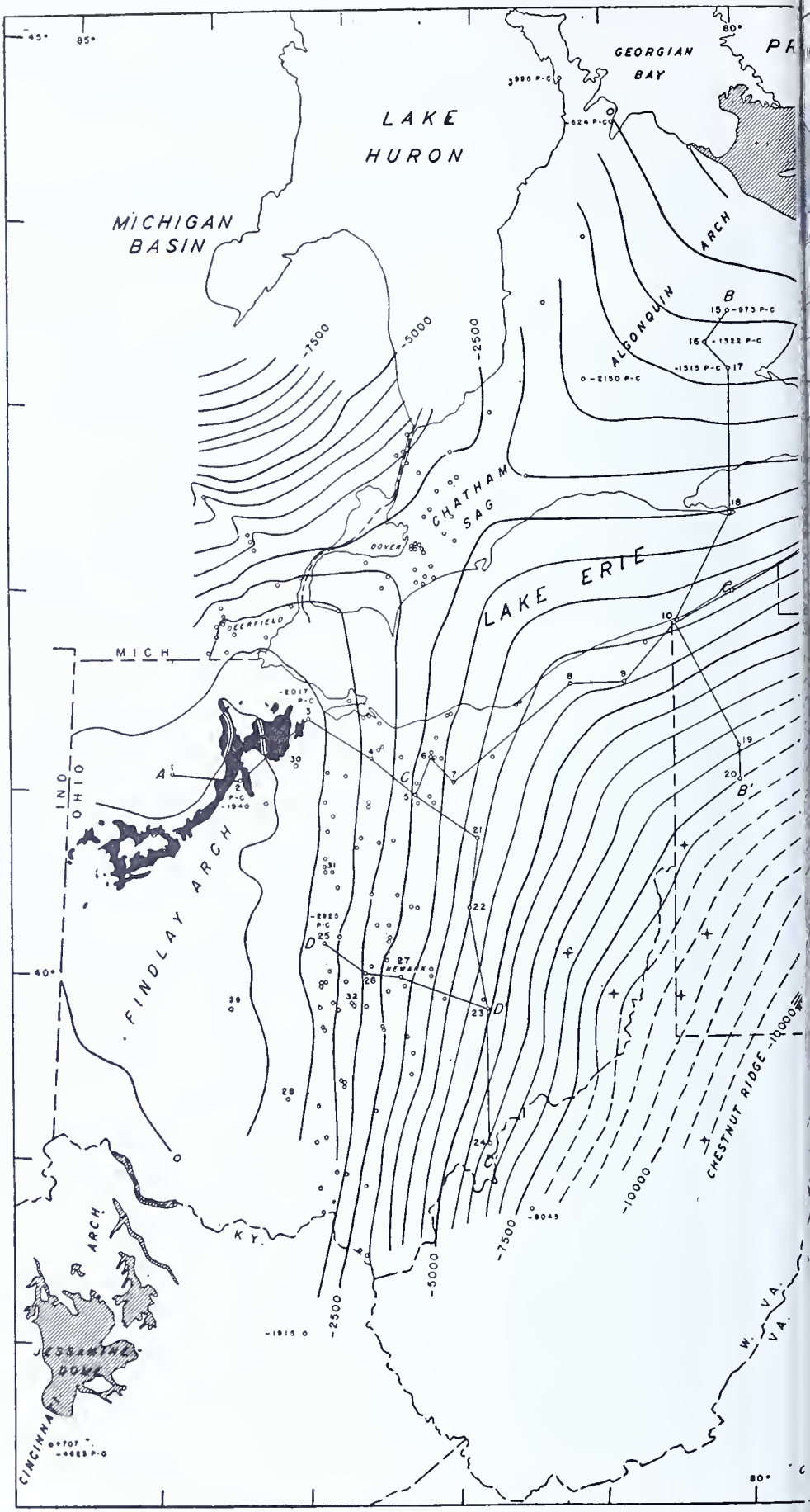
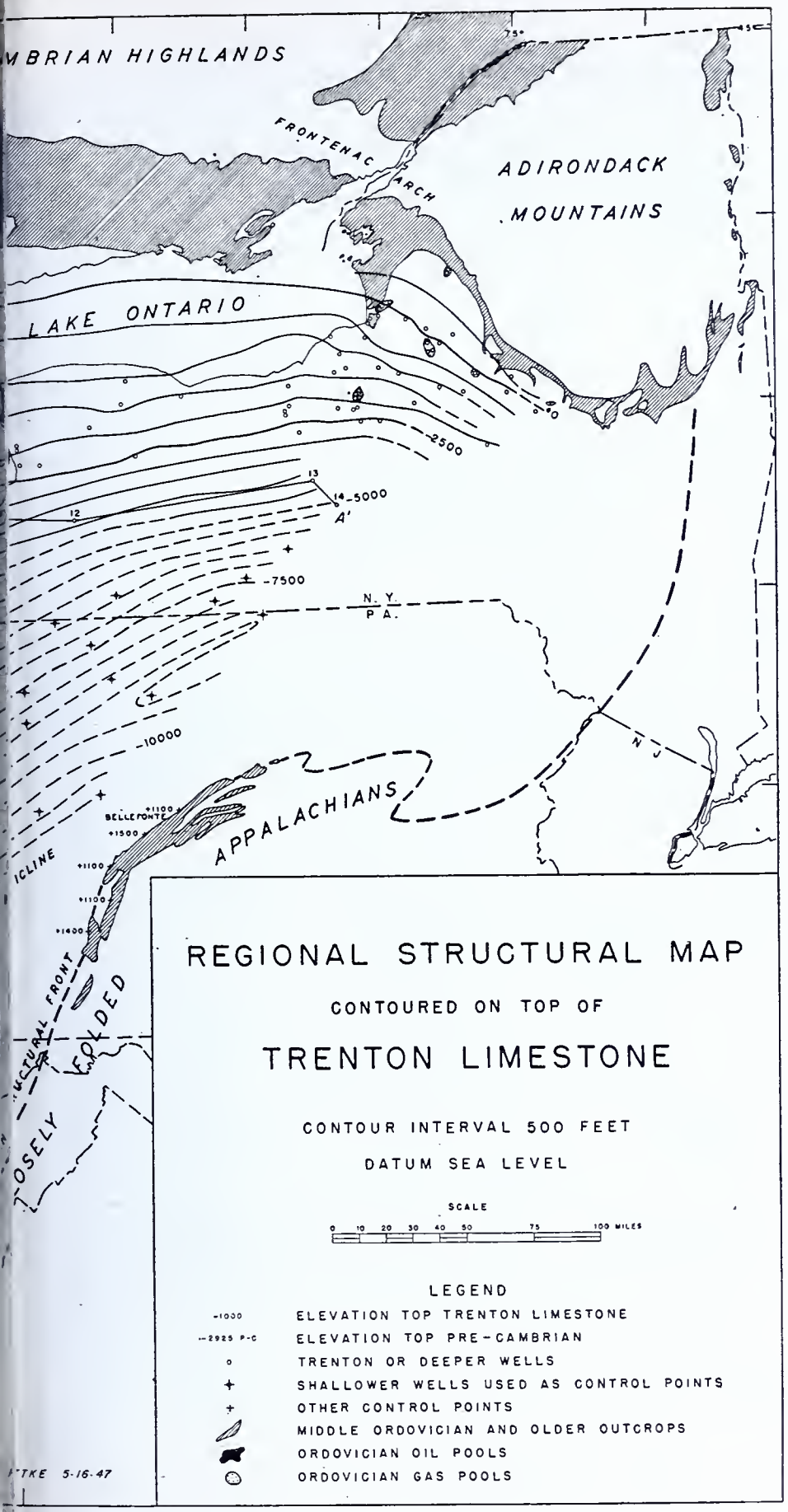


FIG. 1.—Regional structural map



thern part of Appalachian basin.

CORRELATION OF MIDDLE AND LOWER ORDOVICIAN AND CAMBRIAN FORMATIONS AROUND NORTHERN RIM OF APPALACHIAN BASIN

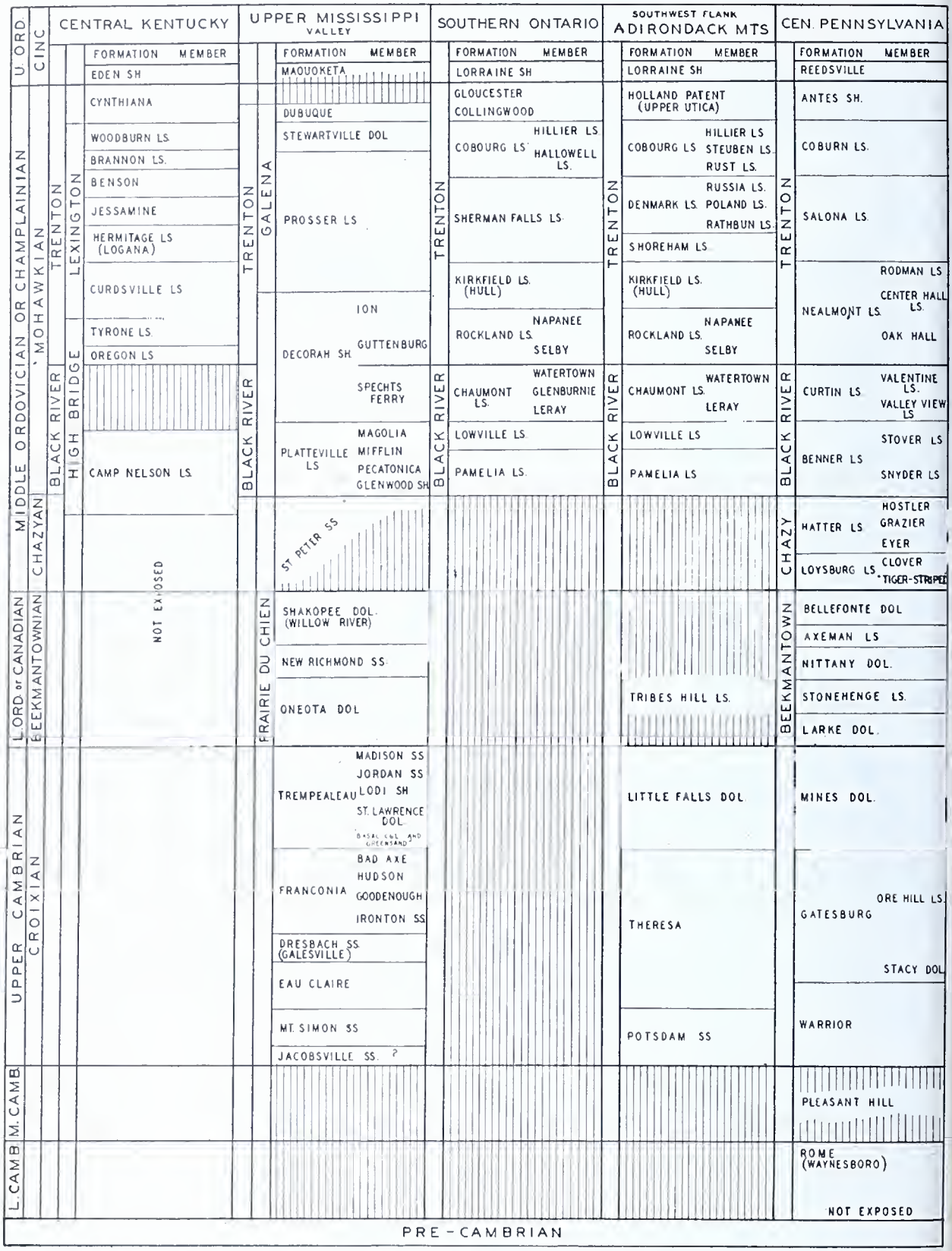


FIG. 2.—Correlation chart of Middle and Lower Ordovician and Cambrian formations around northern rim of Appalachian basin.

has been confined to the outer, relatively shallow margin. Very few wells have been drilled to the Trenton in the deeper parts of the basin. Only five have reached this formation west of the Allegheny front in Pennsylvania and one in West Virginia. Of those in Pennsylvania, three were drilled through the Trenton and Black River groups of the Middle Ordovician and two reached strata of Cambrian age.

STRATIGRAPHY

Upper Cambrian strata rest on pre-Cambrian rocks in the northern part of the Appalachian basin over all but a relatively narrow belt along the northern margin in the vicinity of Lake Ontario where Middle Ordovician beds overlap the Cambrian and rest directly on the pre-Cambrian. Lower Ordovician rocks at the north end of the basin are confined mostly to the eastern part. Middle Ordovician limestones, both Black River and Trenton, extend over the entire area.

OUTCROPS

Outcrops of Trenton and sub-Trenton rocks around the margins of the northern Appalachian basin (Fig. 1) are confined to central Kentucky, southern Ontario, the southwestern flank of the Adirondack Mountains, and the intensely folded and faulted belt east of the Appalachian structural front in eastern New York, northern New Jersey, and central Pennsylvania. They are under cover on the northwest side of the basin over the Findlay arch which separates the Appalachian from the Michigan basin. In this direction they appear first at the surface on the west and northwest margins of the latter basin on the flanks of the Wisconsin arch.

The classification and correlation of the Trenton and sub-Trenton rocks as they are developed on the outcrop in areas adjacent to the Appalachian basin are shown in Figure 2. The chart has been compiled from data obtained from a study of the recent literature covering the areas involved. No attempt has been made to indicate relative thicknesses of the various formations. The closely spaced vertical lines indicate absence of beds in the section.

The name Trenton was first applied to the succession of Middle Ordovician limestone beds that are exposed in the gorge of West Canada Creek, at Trenton Falls, Oneida County, New York, by Vanuxem.[3] Conrad earlier probably intended to include the overlying Utica shale as well as the limestones exposed at Trenton Falls in his Trenton Falls group when he referred to the "Blue fetid limestones and shales of Trenton Falls."[4] In the years that have followed the various members occurring in the vicinity of Trenton Falls have been differentiated and correlated with rocks of similar age in other areas and the term Trenton has been expanded to group rank.

[3] Lardner Vanuxem, "Second Annual Report of so Much of the Third District of the State of New York as Related to Objects of Immediate Utility," *State of New York, Assembly No. 200* (1838), p. 255.

[4] T. A. Conrad, "First Annual Report on the Geological Survey of the Third District of the State of New York," *New York Geol. Survey 1st Ann. Rept.* (1837), pp. 155–86.

On the chart shown in Figure 2, following Kay, the Holland Patent black shale has been included in the Trenton group.[5] Ruedemann has shown that the 300–400 feet of black shale that overlie the Trenton limestone at Holland Patent, Oneida County, New York, constitute the upper division of the Utica shale as developed in the type area.[6] He correlates the Collingwood and Gloucester shales of Ontario with the Holland Patent.[7] Ruedemann considers the Utica shale to constitute an independent basal division of the Cincinnatian which is older than the Eden of the Cincinnati region and is represented by a hiatus in that area.[8] He includes the Cobourg in this division. Parks, on the other hand correlates the Gloucester of Ontario with the Whetstone Gulf or Lower Lorraine of New York, as defined by Ruedemann, and draws the line between the Middle and Upper Ordovician at its base.[9]

In central Pennsylvania, Kay has separated the 400 feet of black shale at the base of the Reedsville shale under the name Antes shale and has correlated this shale with the Holland Patent of New York on lithological and faunal grounds. He includes this shale in the Trenton group.[10]

In the Upper Mississippi Valley the Dubuque formation was considered to constitute the upper member of the Galena group and was correlated with the Collingwood of Ontario by Kay in 1935.[11] Stauffer and Thiel, however, regard the Dubuque in Minnesota[12] to be part of the Maquoketa formation of the late Upper Ordovician. Schuchert also considered the Stewartville formation, which underlies the Dubuque, to be late Upper Ordovician in age.[13]

SUBSURFACE SECTIONS

Six well-sample records have been selected to show the lithologic nature of the Trenton and sub-Trenton formations across the northern part of the Appalachian basin along a section extending from northwestern Ohio to south-central New York south of lakes Erie and Ontario.

The well sections start with the top of the Trenton limestone. The black

[5] G. Marshall Kay, "Stratigraphy of the Trenton Group," *Bull. Geol. Soc. America*, Vol. 48 (1937), p. 286.

[6] Rudolf Ruedemann, "The Utica and Lorraine Formations of New York," *New York State Mus. Bull. 258* (1925), pp. 33–39.

[7] *Ibid.*, pp. 62–64.

[8] *Ibid.*, pp. 147–49.

[9] W. A. Parks, "Faunas and Stratigraphy of the Ordovician Black Shales and Related Rocks in Southern Ontario," *Trans. Royal Soc. Canada*, 3d Ser., Sec. 4 (1928), pp. 59–60.

[10] G. Marshall Kay, "Middle Ordovician of Central Pennsylvania," *Jour. Geol.*, Vol. 52 (1944), p. 114.

[11] G. Marshall Kay, "Ordovician Stewartville-Dubuque Problems," *Jour. Geol.*, Vol. 43 (1935), pp. 561–90.

[12] Clinton R. Stauffer and George A. Thiel, "The Paleozoic and Related Rocks of Southeastern Minnesota," *Minnesota Geol. Survey Bull. 29* (1941), p. 90.

[13] Charles Schuchert, *Stratigraphy of the Eastern and Central United States* (1943), p. 726.

shales which overlie the limestone over much of the northern Appalachian basin have not been included. The black shales lose their dark color gradually as they pass upward into gray shales and, in most instances, it is difficult, if not impossible, to select a definite horizon where the change occurs. As has already been pointed out, there is not yet unanimous agreement among paleontologists and stratigraphers as to just where in the succession of dark shales the line between the Middle and the Upper Ordovician should be drawn on the outcrops, even where fossil evidence is available. The black Utica shales represent a facies of sedimentation during late Middle Ordovician and early Upper Ordovician time and not a time division. The top of the limestone, which is called the top of the Trenton by the drillers, therefore has been called the top of the Middle Ordovician or Champlainian series in the well-sample records with the realization that the horizon selected does not necessarily represent a surface of time equivalence over the whole northern Appalachian basin. Where drillers' logs have to be utilized in connection with subsurface studies, it is the only horizon available.

The six wells for which the records are given are designated as 1, 5, 10, 12, 13, and 20 on the map shown in Figure 1. The records follow.

NO. 1

OHIO OIL COMPANY'S LOUIS BARLAGE WELL NO. 1

Sec. 29, Liberty Township, Putnam County, Ohio. Ottawa Quadrangle, 0.8 mile N. of 41°5′ N. Lat. and 0.4 mile W. of 84°5′ W. Long. Completed, March 21, 1944. Showing of oil at 1,456–1,462 feet in Trenton; hole full of salt water at 2,100 feet and salt water at 2,424 feet in Trempealeau. Elevation, 740 feet above sea-level.

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 598 FEET	
	Top of Trenton limestone	1,432
54	Limestone, fine, crystalline, light brownish gray, dolomitic. Showing of oil at 1,456–1462	1,486
39	Dolomite, very fine, crystalline, light brownish gray	1,525
9	Limestone, very fine, dark grayish brown, somewhat argillaceous, containing fragments of shells, with a little interbedded dark gray, slightly calcareous shale	1,534
46	Limestone, very fine, light grayish to dark grayish brown, containing fragments of shells	1,580
24	Limestone, very fine, grayish to very dark grayish brown, somewhat argillaceous and magnesian, containing abundant fragments of shells, including bryozoans, and a little light gray chert	1,604
21	Limestone, very fine, mottled light to dark brownish gray, containing abundant fragments of shells, with a very little interbedded light greenish gray, calcareous shale	1,625
29	Limestone, very fine, in part crystalline, mottled light to dark brownish gray, somewhat argillaceous, containing fragments of shells, with a little interbedded light gray bentonite	1,654
16	Limestone, very fine, light grayish to grayish brown, somewhat argillaceous, containing fragments of shells and a little light bluish to dark brownish gray chert. 7-inch casing set at 1,670 feet	1,670
24	Limestone, very fine, light grayish brown	1,694
46	Limestone, lithographic, light brownish gray	1,740
10	Limestone, very fine, brownish gray	1,750
95	Limestone, lithographic, light gray to light grayish brown	1,845

Thickness (Feet)	Description of Strata	Depth (Feet)
10	Limestone, very fine, grayish to dark grayish brown	1,855
65	Limestone, very fine, light brownish gray, somewhat magnesian	1,920
80	Limestone, lithographic, brownish gray, somewhat argillaceous	2,000
15	Limestone, very fine, light brownish gray	2,015
15	Limestone, lithographic, brownish gray	2,030
	LOWER ORDOVICIAN OR CANADIAN SERIES, 33 FEET	
	ONEOTA DOLOMITE, 33 FEET	
23	Dolomite, very fine, crystalline, very light brownish gray	2,053
10	Shale, light greenish gray, somewhat dolomitic, with considerable interbedded light greenish gray, dolomitic siltstone	2,063
	UPPER CAMBRIAN SERIES, 1,314 FEET	
	TREMPEALEAU FORMATION, 502 FEET	
35	Dolomite, very fine, very light brownish gray	2,098
254	Dolomite, very fine, crystalline, very light to light brownish gray. Hole full of water at 2,100 feet	2,352
31	Dolomite, very fine, crystalline, brownish gray	2,383
13	Dolomite, very fine, crystalline, dark grayish brown	2,396
44	Dolomite, very fine, crystalline, brownish gray, somewhat argillaceous. Water at 2,424 feet	2,440
12	Shale, gray, silty and somewhat dolomitic	2,452
43	Siltstone, brownish gray, dolomitic	2,495
42	Dolomite, very fine, crystalline, somewhat argillaceous and silty	2,537
28	Dolomite, very fine, crystalline, sandy, containing a little glauconite	2,565
	FRANCONIA SANDSTONE, 25 FEET	
25	Sandstone, fine- to medium-grained, brownish gray, dolomitic, containing a little glauconite, quartz grains angular to subangular	2,590
	DRESBACH SANDSTONE, 10 FEET	
10	Sandstone, fine- to medium-grained, brownish gray, somewhat dolomitic, quartz grains angular to subangular	2,600
	EAU CLAIRE SANDSTONE, 350 FEET	
22	Siltstone, light brownish gray, dolomitic, containing some glauconite, with considerable interbedded gray shale	2,622
18	Shale, gray, with a little interbedded purplish gray shale	2,640
20	Shale, gray, with considerable interbedded light brownish gray dolomitic siltstone, containing abundant glauconite	2,660
5	Siltstone, brownish and greenish gray, dolomitic, containing some glauconite, with some interbedded gray and greenish gray shale	2,665
5	Shale, dark purplish gray, with considerable interbedded greenish gray, dolomitic siltstone containing some glauconite	2,670
20	Sandstone, very fine-grained, gray, dolomitic, with some interbedded greenish gray shale. $5\frac{1}{2}$-inch casing set at 2,677 feet	2,690
32	Siltstone, light gray to brownish and greenish gray, dolomitic, containing a little glauconite, with considerable interbedded gray shale	2,722
11	Sandstone, very fine-grained, reddish brown, somewhat dolomitic	2,733
19	Sandstone, fine- to medium-grained, brownish gray, dolomitic, containing some glauconite; quartz grains angular to subangular	2,752
87	Sandstone, fine-grained, light brownish gray, somewhat dolomitic, containing a little glauconite; quartz grains angular to subangular	2,839
44	Siltstone, brownish and purplish gray, somewhat dolomitic, containing considerable glauconite, with some interbedded purplish gray shale	2,883
17	Sandstone, very fine- to fine-grained, brownish gray, somewhat dolomitic; quartz grains angular to subangular	2,900

Thickness (Feet)	Description of Strata	Depth (Feet)
7	Sandstone, medium-grained, light gray, somewhat dolomitic; quartz grains subangular	2,907
43	Sandstone, fine-grained, light gray to light brownish gray, somewhat dolomitic; quartz grains subangular	2,950
	MOUNT SIMON SANDSTONE, 292 FEET	
8	Sandstone, medium- to coarse-grained, light gray; larger quartz grains subrounded	2,958
74	Sandstone, very fine-grained, light gray	3,032
25	Sandstone, fine-grained, light gray, almost white	3,057
25	Sandstone, fine- to medium-grained, light gray; larger quartz grains subrounded	3,082
10	Sandstone, coarse-grained, light gray; many of quartz grains subrounded	3,092
48	Sandstone, coarse- to very coarse-grained, light reddish gray; most of quartz grains subangular, a few rounded and frosted	3,140
79	Sandstone, medium- to coarse-grained, light reddish gray; many of larger quartz grains subrounded and frosted	3,219
23	Sandstone, fine-grained, light reddish gray; quartz grains subangular	3,242
	JACOBSVILLE SANDSTONE, 135 FEET	
58	Sandstone, fine-grained, grayish red, somewhat argillaceous, containing some pink orthoclase and a little muscovite	3,300
77	Arkose, grayish red, composed of quartz, some partly altered pink, orthoclase, and a little muscovite, all stained red by ferric oxide; quartz grains subangular to subrounded	3,377
	Total depth	3,377

NO. 5

Ohio Oil Company's S. V. Krause Well No. 1

Tract 14, Ruggles Township, Ashland County, Ohio. New London Quadrangle, 1.19 miles N. of 41°00′ N. Lat. and 1.2 miles W. of 82°20′ W. Long. Completed, 1945. 260,000 cubic feet of gas and showing of oil at 4,420–4,434 feet and 40 bailers of salt water per day at 4,537–4,543 in Trempealeau; hole full of salt water at 4,683–4,692 in Dresbach; 30 bailers of salt water per day at 4,805–4,814 and hole full of salt water at 5,041–5,048 feet in Eau Claire. Elevation, 1,114 feet above sea-level.

Thickness (Feet)	Description of Strata	Depth (Feet)
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 660 FEET	
	Top of Trenton limestone	3,758
5	Limestone, very fine, dense, gray to dark grayish brown, argillaceous and slightly magnesian, containing abundant fragments of shells	3,763
	Bottom of $6\frac{5}{8}$-inch casing	3,763
55	Limestone, very fine, crystalline, grayish brown, somewhat argillaceous and slightly magnesian, containing some light gray to brownish gray chert and abundant fragments of shells	3,818
35	Limestone, very fine, dense, brownish gray, argillaceous and slightly magnesian, containing fragments of shells and a little brownish gray chert	3,853
39	Limestone, very fine, dense, light brownish gray, argillaceous, containing fragments of shells, with some interbedded light gray bentonite	3,892
26	Limestone, very fine, dense, brownish gray, argillaceous, with some interbedded light gray bentonite	3,918
20	Limestone, very fine, dense, light brownish gray, somewhat argillaceous, containing a little light gray chert	3,938
28	Limestone, very fine, dense, light brownish gray, containing fragments of shells	3,966
22	Limestone, very fine, dense, brownish gray	3,988
74	Limestone, very fine, dense, light brownish gray, containing fragments of shells	4,062
58	Limestone, very fine, dense, grayish brown, containing fragments of shells	4,120

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
191	Limestone, very fine, dense, light brownish gray	4,311
16	Limestone, very fine, dense, light brownish gray with a little interbedded greenish gray, slightly calcareous shale	4,327
46	Limestone, very fine, dense, light brownish gray, somewhat argillaceous and magnesian	4,373
16	Limestone, very fine, dense, grayish brown, with some interbedded greenish gray, calcareous shale	4,389
25	Limestone, very fine, dense, grayish brown, with much interbedded grayish green, somewhat calcareous shale	4,414
4	Shale, grayish green	4,418
	UPPER CAMBRIAN SERIES, 833+FEET	
	TREMPEALEAU AND FRANCONIA FORMATIONS, 265 FEET	
22	Sandstone, very fine-grained, light buff, almost white, quartzose and dolomitic. 260,000 cubic feet gas per 24 hours I.O.F., with slight showing of oil at 4,420–4,434; salt water at 4,432 feet	4,440
16	Shale, gray, silty, with a great deal of interbedded light gray siltstone containing some muscovite	4,456
8	Siltstone, light brownish gray, dolomitic	4,464
8	Sandstone, very fine-grained, light buff, quartzose and dolomitic, with considerable interbedded greenish gray shale	4,472
101	Dolomite, very fine, crystalline, light buff, silty. 40 bailers salt water per day at 4,537–4,543 feet	4,573
14	Dolomite, very fine, crystalline, brownish gray, silty	4,587
7	Dolomite, very fine, crystalline, brownish gray, silty, containing minute grains of glauconite	4,594
54	Dolomite, very fine, crystalline, light grayish brown, containing some fine quartz grains, the larger of which are rounded and frosted	4,648
22	Dolomite, very fine, crystalline, light grayish brown, containing much fine-grained quartz sand, some of the larger grains of which are rounded and frosted	4,670
13	Dolomite, very fine, crystalline, light buff, containing some fine quartz grains, some of which are rounded and frosted	4,683
	DRESBACH SANDSTONE, 57 FEET	
7	Sandstone, fine- to medium-grained, light buff, quartzose and dolomitic, many of quartz grains rounded and frosted	4,690
13	Sandstone, medium-grained, light buff, quartzose and slightly dolomitic, with larger quartz grains rounded and frosted. Hole full of salt water at 4,683–4,692	4,703
37	Sandstone, very fine- to fine-grained, light buff, quartzose and somewhat dolomitic, with some of larger quartz grains rounded and frosted	4,740
	EAU CLAIRE SANDSTONE, 385 FEET	
6	Sandstone, very fine- to fine-grained, light buff, quartzose, with considerable interbedded dark brownish gray, somewhat dolomitic siltstone	4,746
16	Sandstone, very fine- to fine-grained, brownish gray, quartzose and dolomitic, with some quartz grains rounded and frosted	4,762
10	Sandstone, very fine- to fine-grained, light buff, quartzose and somewhat dolomitic, with some quartz grains rounded and frosted	4,772
22	Sandstone, very fine- to fine-grained, light buff, quartzose and dolomitic, with some of larger quartz grains rounded and frosted, with considerable interbedded dark brownish gray dolomitic siltstone containing a little glauconite	4,794
	Bottom of $5\frac{1}{2}$-inch casing	4,780
23	Sandstone, very fine- to fine-grained, light grayish brown, quartzose and dolomitic, with some of quartz grains rounded and frosted. 30 bailers salt water per day at 4,805–4,814 feet	4,817
44	Dolomite, very fine, crystalline, light buff, containing a few very fine to fine quartz grains, some of the larger of which are rounded and frosted	4,861
40	Dolomite, very fine, crystalline, light grayish brown, containing some very fine to fine quartz sand, some of quartz grains rounded and frosted	4,901
132	Dolomite, very fine, crystalline, light brownish gray, sandy; quartz grains very fine to fine, some rounded and frosted	5,033

Thickness (Feet)	Description of Strata	Depth (Feet)
52	Dolomite, very fine, crystalline, dark grayish brown, sandy; quartz grains very fine to fine, some rounded and frosted, many possess secondary crystal facets. Hole full of salt water at 5,041–5,048	5,085
14	Sandstone, fine-grained, brownish gray, quartzose and dolomitic, some of quartz grains rounded and frosted, many possess secondary crystal facets	5,099
7	Dolomite, very fine, crystalline, grayish brown, sandy	5,106
8	Sandstone, fine- to medium-grained, dark brownish gray, quartzose and somewhat dolomitic, some of quartz grains rounded and frosted, many possess secondary crystal facets	5,114
11	Sandstone, fine- to medium-grained, brownish gray, quartzose and dolomitic, some of quartz grains rounded and frosted, many possess secondary crystal facets	5,125
	MOUNT SIMON SANDSTONE, 126+FEET	
11	Sandstone, fine- to medium-grained, light gray, quartzose, some of quartz grains rounded and frosted, many possess secondary crystal facets	5,136
5	Sandstone, fine-grained, light gray, quartzose and somewhat dolomitic, some of quartz grains rounded and frosted, many possess secondary crystal facets	5,141
33	Sandstone, fine- to medium-grained, light gray, quartzose, some of grains rounded and frosted, many possess secondary crystal facets	5,174
77	Sandstone, medium-grained, light gray, quartzose, with many grains rounded and frosted	5,251
	Total depth	5,251

NO. 10

OHIO OIL COMPANY'S JAY CHILDS WELL NO. 1

Springfield Township, Erie County, Pennsylvania. Girard Quadrangle, 2.23 miles S. of 42°00′ N. Lat. and 0.95 mile W. of 80°30 W. Long. Completed, March 30, 1941. Showing of gas and one barrel of oil per day at 4,441 feet and a little salt water at 4,460 feet in Trenton; slight showing of gas and oil and a little salt water, 5,182–5,188 feet, more salt water, 5,188–5,191 feet, rose 3,000 feet, in Dresbach. Elevation: 638 feet above sea-level.

Thickness (Feet)	Description of Strata	Depth (Feet)
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 742 FEET	
	Top of Trenton limestone	4,437
25	Limestone, very fine, crystalline, light grayish brown, slightly magnesian. Showing of oil, about one barrel per day, at 4,441 and a little salt water at 4,460 feet	4,462
17	Limestone, very fine, dense, very dark grayish brown, somewhat argillaceous, with considerable interbedded very fine, crystalline, light grayish brown limestone containing fragments of shells	4,479
45	Limestone, very fine, dense, very dark brownish gray, somewhat argillaceous, containing fragments of shells	4,524
24	Limestone, very fine, dense, very dark brownish gray, argillaceous, containing fragments of shells	4,548
42	Limestone, very fine, dense, light to dark brownish gray, argillaceous, containing fragments of shells	4,590
17	Limestone, very fine, dense, very dark brownish gray, argillaceous	4,607
10	Shale, grayish black, calcareous, with considerable interbedded, very fine, dense, very dark brownish gray, argillaceous limestone	4,617
59	Limestone, very fine, dense, very dark, brownish gray, argillaceous, containing fragments of shells	4,676
46	Limestone, very fine, dense, very dark brownish gray, somewhat argillaceous, containing fragments of shells	4,722
40	Limestone, very fine, crystalline, grayish brown, containing abundant fragments of shells, with some interbedded very fine, dense, very dark brownish gray, somewhat argillaceous limestone	4,762

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
11	Limestone, very fine, dense, dark grayish brown, argillaceous, containing fragments of shells and a little brownish gray chert	4,773
	Top of bentonite zone	4,773
7	Limestone, very fine, dense, dark grayish brown, argillaceous, containing fragments of shells and considerable brownish gray chert, with some interbedded light gray bentonite	4,780
11	Limestone, very fine, dense, dark grayish brown, argillaceous, containing fragments of shells, with considerable interbedded light gray bentonite	4,791
11	Limestone, very fine, dense, grayish brown, argillaceous, with a little interbedded light gray bentonite	4,802
11	Bentonite, light gray, with a little interbedded very fine, dense, grayish brown, argillaceous limestone	4,813
7	Bentonite, light gray, with some interbedded, very fine, dense, grayish brown, argillaceous limestone	4,820
10	Limestone, very fine, dense, grayish brown, argillaceous, with considerable interbedded light gray bentonite; limestone contains some brownish gray chert	4,830
	Bottom of bentonite zone	4,830
150	Limestone, very fine, dense, grayish brown; contains a little brownish gray chert and occasional fragments of shells	4,980
13	Limestone, very fine, crystalline, grayish brown, somewhat magnesian; contains minutely porous light gray chert	4,993
34	Limestone, very fine, dense, grayish brown; contains fragments of shells	5,027
50	Limestone, very fine, dense, dark grayish brown; contains fragments of shells	5,077
13	Limestone, very fine, dense, dark brownish gray, somewhat argillaceous	5,090
13	Limestone, very fine, dense, gray to dark greenish gray, argillaceous	5,103
7	Limestone, very fine, dense, dark brownish gray, argillaceous	5,110
27	Limestone, very fine, dense, grayish brown; contains fragments of shells	5,137
13	Limestone, very fine, dense, dark grayish brown	5,150
6	Limestone, very fine, crystalline, dark grayish brown, sandy, and argillaceous; fine quartz grains mostly subangular, but some are subrounded to rounded and frosted	5,156
5	Limestone, very fine, dense, dark gray, shaly	5,161
4	Limestone, very fine, crystalline, dark grayish brown, somewhat argillaceous	5,165
6	Limestone, very fine, dense, very dark brownish gray, somewhat argillaceous and magnesian	5,171
8	Shale, gray	5,179
	UPPER CAMBRIAN SERIES, 12+ FEET	
	DRESBACH SANDSTONE, 12+ FEET	
5	Sandstone, fine- to medium-grained, light gray to white, somewhat dolomitic; quartz grains subrounded to rounded and frosted	5,184
7	Sandstone, fine- to medium-grained, light gray to white; quartz grains subrounded to rounded and frosted. Slight showing of gas and oil and a little salt water, 5,185–5,188 feet; more salt water, 5,188–5,191 feet, rose 3,000 feet in hole	5,191
	Total depth	5,191

NO. 12

K. R. Wilson's Arcade Well No. 1

Town of Arcade, Wyoming County, New York. Arcade Quadrangle, 2.11 miles N. of 42°11′ N. Lat. and 0.35 mile W. of 78°25′ W. Long. Completed, August 21, 1946. Showing of oil and a little gas at 5,994 feet and showing of gas at 6,030 feet in Black River; 25,000 cubic feet of gas at 6,182 feet in Tribes Hill; salt water, 6,375–6,395 feet in Theresa; salt water at 7,040 feet in Potsdam. Elevation: 1,483 feet above sea-level.

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 767 FEET	
	Top of Trenton limestone	5,342
31	Limestone, very fine, dense, dark brownish gray, argillaceous, containing fragments of shells, with considerable interbedded dark gray shale	5,373

Thickness (Feet)	Description of Strata	Depth (Feet)
20	Limestone, very fine, dense, dark brownish gray, argillaceous, containing fragments of shells	5,393
55	Limestone, very fine, crystalline to dense, mottled light and dark brownish gray, containing abundant fragments of shells	5,448
208	Limestone, dark gray, shaly, containing fragments of shells	5,656
63	Limestone, very fine, dense, dark brownish gray, argillaceous, containing fragments of shells, with some interbedded very dark gray, calcareous shale	5,719
118	Limestone, very fine, crystalline, brownish gray, containing fragments of shells, with considerable interbedded dark brownish gray shaly limestone	5,837
16	Limestone, very fine, dense, dark brownish gray, somewhat argillaceous, containing fragments of shells	5,863
39	Limestone, very fine, dense, brownish gray, somewhat argillaceous, with a little interbedded light gray bentonite	5,892
72	Limestone, very fine, dense, brownish gray, somewhat argillaceous	5,964
16	Limestone, very fine, dense, brownish gray, somewhat argillaceous, with a little interbedded slightly calcareous black shale	5,980
8	Limestone, very fine, dense, brownish to dark brownish gray, somewhat argillaceous	5,988
36	Limestone, very fine, dense, brownish gray, argillaceous, with some interbedded light greenish gray bentonite	6,024
23	Limestone, very fine, crystalline, brownish gray, dolomitic, with a great deal of interbedded, very fine, dense, brownish gray, somewhat argillaceous limestone. Showing of gas at 6,030 feet	6,047
15	Limestone, very fine, crystalline, brownish gray	6,062
11	Limestone, very fine, dense, light brownish to brownish gray, slightly magnesian	6,073
19	Limestone, very fine, dense to crystalline, light brownish to brownish gray, somewhat argillaceous and slightly magnesian	6,092
17	Limestone, very fine, dense, light gray, somewhat argillaceous and slightly magnesian	6,109
	LOWER ORDOVICIAN OR CANADIAN SERIES, 86 FEET	
	TRIBES HILL LIMESTONE, 86 FEET	
12	Limestone, very fine, dense, brownish gray, somewhat magnesian	6,121
7	Limestone, fine, oölitic, argillaceous, silty and slightly magnesian; oölites, dark brownish gray and matrix, light gray	6,128
5	Limestone, very fine, dense, dark brownish gray, argillaceous	6,133
8	Limestone, fine, oölitic, argillaceous, silty and slightly magnesian; oölites, dark brownish gray and matrix, light gray	6,141
31	Limestone, very fine, crystalline, light gray, somewhat argillaceous, silty and magnesian, with a few fine subrounded and frosted quartz grains in upper part	6,172
17	Limestone, very fine, dense to very fine, crystalline, light brownish gray, argillaceous, silty and somewhat magnesian. 25,000 cubic feet of gas at 6,182	6,189
6	Limestone, light gray, shaly, silty and somewhat magnesian, containing a few fine- to medium-rounded and frosted quartz grains	6,195
	UPPER CAMBRIAN SERIES, 949+ FEET	
	LITTLE FALLS DOLOMITE, 130 FEET	
5	Dolomite, fine, crystalline, light brownish gray containing considerable very fine to fine quartz sand, the larger grains of which are subrounded and frosted	6,200
57	Dolomite, fine, crystalline, light brownish gray	6,257
32	Dolomite, fine, crystalline, light gray	6,289
10	Dolomite, fine, crystalline, light gray, containing considerable very fine to fine, angular quartz sand, with a few of the larger grains subrounded and frosted	6,299
12	Dolomite, fine, crystalline, light gray, containing much very fine to fine poorly sorted, subangular quartz sand, with a few rounded and frosted grains to 0.5 millimeter in diameter	6,311
5	Sandstone, fine- to medium-grained, light brownish gray, quartzose and dolomitic with some of larger quartz grains rounded and frosted	6,316
9	Dolomite, very fine, crystalline, light brownish gray, containing a great deal of very fine to fine, poorly sorted, subangular quartz sand, with a few of larger grains rounded and frosted	6,325

Thickness (Feet)	Description of Strata	Depth (Feet)
	THERESA FORMATION, 643 FEET	
10	Sandstone, fine- to medium-grained, light brownish gray, quartzose and somewhat dolomitic, with most of quartz grains subangular, some larger grains, rounded and frosted	6,335
7	Sandstone, fine- to medium-grained, light brownish gray, quartzose and slightly dolomitic, with most of quartz grains subangular, some larger grains, rounded and frosted	6,342
26	Sandstone, fine-grained, light gray to light brownish gray, subangular, quartzose, with a few larger grains rounded and frosted	6,368
23	Sandstone, medium-grained, light brownish gray, subangular, quartzose, with some larger grains rounded and frosted. Salt water at 6,375–6,395	6,391
43	Sandstone, fine- to medium-grained, poorly sorted light gray to light brownish gray, subangular, quartzose, with some larger grains rounded and frosted	6,434
32	Sandstone, fine-grained, light brownish gray, subangular, quartzose, with a few larger grains rounded and frosted	6,466
4	Dolomite, very fine, dense, light brownish gray, argillaceous and silty	6,470
7	Dolomite, very fine, crystalline, light gray, containing considerable fine- to medium-grained, poorly sorted quartz sand, with many rounded and frosted grains	6,477
13	Sandstone, medium-grained, light gray, quartzose and somewhat dolomitic, containing many rounded and frosted grains	6,490
24	Sandstone, fine-grained, light gray, quartzose and somewhat dolomitic, subangular with few rounded and frosted grains	6,514
52	Dolomite, very fine, crystalline, light gray to light brownish gray, containing some very fine to fine subangular quartz sand, with a few grains rounded and frosted	6,566
4	Sandstone, very fine-grained, light brownish gray, quartzose and somewhat dolomitic, angular	6,570
18	Sandstone, very fine-grained, light brownish gray, quartzose and somewhat dolomitic, subangular, with a few of larger grains rounded and frosted	6,588
13	Dolomite, very fine, crystalline, light brownish gray, containing some fine, subangular quartz sand, with a few of larger grains rounded and frosted	6,601
5	Sandstone, fine-grained, light brownish gray, quartzose and somewhat dolomitic, subangular, with a few larger grains rounded and frosted	6,606
10	Dolomite, very fine, crystalline, light brownish gray, containing some very fine to fine subangular quartz sand with some larger grains rounded and frosted	6,616
10	Dolomite, very fine, crystalline, light brownish gray, containing some very fine to fine subangular quartz sand with a few grains rounded and frosted and some chalk-textured chert	6,626
15	Dolomite, very fine, crystalline, light brownish gray, containing some very fine, subangular quartz sand	6,641
47	Dolomite, very fine, crystalline, light brownish gray, containing considerable very fine, subangular quartz sand	6,688
33	Dolomite, very fine to fine, crystalline, brownish gray, containing some very fine to fine angular quartz sand with a few larger grains rounded and frosted	6,721
34	Dolomite, very fine, crystalline, brownish gray, containing considerable very fine, angular quartz sand and silt and some dark gray clay	6,755
5	Dolomite, very fine, crystalline, brownish gray, containing some very fine, angular quartz sand and silt and some dark gray clay	6,760
70	No samples	6,830
24	Dolomite, very fine, crystalline, dark brownish gray, containing much very fine, subangular quartz sand and some dark gray clay	6,854
25	Sandstone, fine-grained, light brownish gray, subangular quartzose and somewhat dolomitic	6,897
5	Dolomite, very fine, crystalline, light brownish gray, containing some very fine subangular quartz sand and gray clay	6,884
2	Sandstone, fine- to medium-grained, light brownish gray, quartzose and slightly dolomitic, subangular, with some larger grains rounded and frosted	6,886
11	Sandstone, very fine- to fine-grained, light brownish gray, quartzose and slightly dolomitic	6,897
3	Dolomite, very fine, crystalline, brownish gray, containing considerable very fine to fine subangular quartz sand	6,900

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
20	Dolomite, very fine, crystalline, dark brownish gray, containing some very fine to fine subangular quartz sand	6,920
48	Dolomite, very fine, crystalline, brownish gray, containing considerable very fine to fine subangular quartz sand with few rounded and frosted grains	6,968
	POTSDAM SANDSTONE, 176 FEET	
32	Sandstone, very fine- to fine-grained, light brownish gray, quartzose and somewhat dolomitic, subangular with few rounded and frosted grains	7,000
15	Sandstone, very fine- to fine-grained, light brownish gray, quartzose and dolomitic, subangular, with few rounded and frosted grains	7,015
12	Dolomite, very fine, crystalline, dark brownish gray, containing considerable very fine to fine, subangular quartz sand with few rounded and frosted grains	7,027
38	Sandstone, fine-grained, light gray, quartzose and slightly dolomitic, subangular, with few rounded and frosted grains. Salt water at 7,040 feet, rose 5,500 feet	7,065
30	Sandstone, very fine- to fine-grained, light brownish gray, slightly calcareous; quartz grains, mostly subangular	7,095
8	Sandstone, very fine- to fine-grained, light brownish gray, somewhat dolomitic; quartz grains, subangular; a little interbedded light greenish gray, silty, and micaceous shale	7,103
6	Sandstone, very fine- to fine-grained, light brownish gray; quartz grains, subangular	7,109
15	Sandstone, very fine-grained, light brownish gray, with a little interbedded dark gray shale	7,124
9	Sandstone, very fine-grained, light brownish gray, slightly dolomitic and containing a little muscovite	7,133
11	Sandstone, very fine-grained, light pink, containing a few orthoclase grains and a little muscovite; quartz grains, subangular	7,144
	Total depth	7,144

NO. 13

RESERVE OIL COMPANY'S J. C. MAHANEY WELL NO. 1

Town of Ledyard, Cayuga County, New York. Genoa Quadrangle, 1.3 miles N. of 42°40′ N. Lat. and 1.2 miles E. of 76°40′ W. Long. Completed, May, 1931. Elevation: 824 feet above sea-level.

Thickness (Feet)	*Description of Strata*	*Depth (Feet)*
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 833 FEET	
	Top of Trenton limestone	5,054
13	Limestone, very fine, crystalline, mottled light and dark brownish gray, somewhat argillaceous, containing fragments of shells	5,067
49	Limestone, very fine, very dark gray, argillaceous, containing fragments of shells	5,116
38	Limestone, very fine, very dark gray, shaly, containing fragments of shells, with some interbedded light gray bentonite	5,154
16	Limestone, very fine, very dark gray, argillaceous, containing fragments of shells	5,170
15	Limestone, very fine, very dark gray, shaly, containing fragments of shells including crinoid stems, with considerable interbedded light gray bentonite	5,185
10	Limestone, very fine, very dark gray, shaly, with a little interbedded light gray bentonite	5,195
10	Limestone, very fine, very dark gray, shaly, containing fragments, of shells	5,205
29	Limestone, very fine, very dark gray, shaly, with some interbedded light gray bentonite	5,234
31	Limestone, very fine, very dark gray, shaly, with little interbedded light gray bentonite	5,265
8	Shale, very dark gray, very calcareous	5,273
15	Limestone, very fine, very dark gray, shaly	5,288
41	Shale, very dark gray, very calcareous	5,329
78	Limestone, very fine, very dark gray, argillaceous, containing fragments of shells	5,407
26	No samples	5,433

Thickness (Feet)	Description of Strata	Depth (Feet)
12	Limestone, very fine, very dark gray, shaly	5,445
81	Limestone, very fine, very dark gray, shaly, with some interbedded, very fine, crystalline, brownish gray limestone containing fragments of shells	5,526
38	Limestone, very fine, crystalline, brownish gray, containing fragments of shells, with a great deal of interbedded, very dark gray, shaly limestone	5,564
32	Limestone, very fine, very dark gray, shaly, with some interbedded, very fine, crystalline, dark brownish gray limestone, containing fragments of shells	5,596
63	Limestone, very fine, very dark gray, shaly	5,659
14	No samples	5,673
15	Shale, very dark gray, calcareous, with some interbedded very fine, dark gray argillaceous limestone and a little light gray bentonite	5,688
82	Limestone, lithographic, dark brownish gray, slightly argillaceous	5,770
12	Limestone, lithographic, light to dark brownish gray	5,872
71	Limestone, very fine, dark brownish gray, somewhat argillaceous and magnesian	5,853
34	Limestone, very fine, very dark brownish gray, somewhat argillaceous and magnesian	5,887
	LOWER ORDOVICIAN OR CANADIAN SERIES, 211 FEET	
	TRIBES HILL LIMESTONE, 211 FEET	
35	Limestone, very fine, light to dark brownish gray, argillaceous and somewhat magnesian	5,922
84	Limestone, very fine, light gray, argillaceous, containing a few fine- to medium-sized subrounded and frosted quartz grains	6,006
6	Limestone, very fine, light gray, argillaceous and somewhat magnesian	6,012
6	Limestone, very fine, light gray, sandy and somewhat magnesian; quartz grains very fine to fine, with some larger grains subrounded and frosted	6,018
6	Limestone, very fine, light gray, silty, argillaceous and somewhat magnesian, containing a few rounded and frosted quartz grains	6,024
37	Limestone, very fine, light gray to gray, argillaceous and somewhat magnesian	6,061
16	Limestone, very fine, crystalline, light gray, dolomitic	6,077
21	Limestone, very fine, crystalline, light gray, dolomitic and argillaceous	6,098
	UPPER CAMBRIAN SERIES, 68 FEET	
	LITTLE FALLS DOLOMITE, 68 FEET	
10	Dolomite, very fine to fine, crystalline, light gray	6,108
31	Dolomite, very fine, crystalline, light gray, somewhat silty, containing an occasional fine- to medium-sized subrounded and frosted quartz grain	6,139
12	Dolomite, fine, crystalline, light gray, somewhat silty	6,151
5	Dolomite, very fine, crystalline, light gray, silty and sandy, containing some fine to medium-sized subrounded and frosted quartz grains	6,156
10	No samples	6,166
	Total depth	6,166

NO. 20

MANUFACTURERS LIGHT AND HEAT COMPANY'S JESSIE G. HOCKENBERRY WELL NO. 1

Mercer Township, Butler County, Pennsylvania. Mercer Quadrangle, 1.61 miles N. of 41°45′ N. Lat. and 2.13 miles W. of 80°00′ W. Long. Completed, November 10, 1944. Showing of gas, 9,505–9,510 feet in Black River, good showing of gas, 9,746–9,771 feet in Mines, acidized without results; one bailer salt water per hour at 10,092 feet in Gatesburg. Elevation: 1,306 feet above sea-level.

Thickness (Feet)	Description of Strata	Depth (Feet)
	MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES, 741 FEET	
	Top of Trenton limestone	8,812
22	Limestone, very fine, dense, very dark gray, almost black, slightly magnesian, containing abundant fragments of shells, with some interbedded grayish black, calcareous shale	8,834

Thickness (Feet)	Description of Strata	Depth (Feet)
14	Limestone, very fine, crystalline, dark brownish gray, somewhat silty and argillaceous and slightly magnesian, containing abundant fragments, of shells and a little black dense chert, with some interbedded grayish black, calcareous shale	8,848
18	Limestone, very fine, crystalline, dark brownish gray, silty and argillaceous, slightly magnesian, containing abundant fragments of shells and a little brownish gray dense dense chert, with some interbedded dark gray, somewhat calcareous shale	8,866
12	Limestone, dark gray, shaly, with considerable interbedded, very fine, crystalline, dark brownish gray, argillaceous limestone, containing abundant fragments of shells	8,878
14	Limestone, very fine, crystalline, brownish gray, argillaceous, with considerable interbedded, dark gray, shaly limestone	8,892
19	Limestone, dark to very dark gray, shaly, with considerable interbedded, very fine, crystalline, dark brownish gray, argillaceous limestone, containing abundant fragments of shells	8,911
39	Limestone, very fine, dense, dark brownish gray, argillaceous and slightly magnesian, containing abundant fragments of shells, with some interbedded, very dark gray, somewhat calcareous shale	8,950
32	Limestone, very fine, dense, dark to very dark brownish gray, argillaceous and slightly magnesian, containing fragments of shells	8,982
12	Shale, very dark gray, calcareous, with some interbedded, very fine, dense, dark brownish gray, argillaceous and slightly magnesian limestone and a very little light gray bentonite	8,994
17	Limestone, very fine, dense, dark brownish gray, somewhat argillaceous and slightly magnesian, containing abundant fragments of shells	9,011
9	Limestone, very fine, dense, very dark brownish gray, somewhat argillaceous and slightly magnesian, containing fragments of shells, with a little interbedded light gray bentonite	9,020
14	Limestone, very fine, dense, very dark brownish gray, somewhat argillaceous, containing fragments of shells	9,034
16	Limestone, very fine, dense, light gray, to gray, slightly magnesian	9,050
55	Limestone, very fine, dense, dark brownish gray, somewhat argillaceous and slightly magnesian	9,105
21	Limestone, very fine, dense, light gray to brownish gray, somewhat argillaceous and slightly magnesian	9,126
83	Limestone, very fine, dense, dark brownish gray, slightly magnesian	9,209
16	Limestone, very fine, crystalline, light to dark brownish gray, slightly magnesian	9,225
46	Limestone, very fine, dense, brownish to dark brownish gray, slightly magnesian, containing fragments of shells	9,271
117	Limestone, very fine, dense, dark to very dark brownish gray, slightly argillaceous and magnesian	9,388
40	Limestone, very fine, dense, gray, argillaceous, with some interbedded dark brownish gray calcareous shale	9,428
11	Limestone, very fine, dense, brownish to dark brownish gray, somewhat argillaceous and magnesian	9,439
11	Limestone, very fine, crystalline, brownish gray, somewhat magnesian	9,450
48	Limestone, very fine, dense, dark to very dark brownish gray, argillaceous and somewhat magnesian	9,498
7	Limestone, very fine, oölitic, dark brownish gray, argillaceous and somewhat magnesian	9,505
30	Limestone, very fine, dense, dark brownish gray, argillaceous and somewhat magnesian, with some interbedded gray to dark gray, somewhat calcareous shale. Show of gas, 9,505–9,510	9,535
13	Limestone, very fine, dense, light gray to gray, argillaceous and dolomitic	9,548
5	Shale, very dark brownish gray, calcareous, with some interbedded, very fine, dense, gray, argillaceous and dolomitic limestone	9,553

LOWER ORDOVICIAN OR CANADIAN SERIES, 187 FEET

LARKE DOLOMITE, 187 FEET

5	Dolomite, fine, crystalline, light brownish gray, containing some light gray, dense chert	9,558

Thickness (Feet)	Description of Strata	Depth (Feet)
2	Dolomite, fine, crystalline, light brownish gray, containing some light gray, dense chert, and a few subrounded to rounded, frosted quartz grains	9,560
20	Dolomite, fine to medium, crystalline, light brownish gray	9,580
14	Dolomite, fine to medium, crystalline, light brownish gray containing a little light gray, dense chert	9,594
68	Dolomite, fine to medium, crystalline, light gray to light brownish gray	9,662
78	Dolomite, fine, crystalline, light brownish gray, containing small drusy cavities lined with minute dolomite crystals	9,740
	UPPER CAMBRIAN SERIES, 356 FEET	
	MINES DOLOMITE, 308 FEET	
6	Dolomite, fine crystalline, mottled light brownish gray and black	9,746
13	Dolomite, very fine to fine, crystalline, light brownish gray, slightly silty	9,759
24	Dolomite, very fine to fine, crystalline, light gray, containing a few rounded and frosted quartz grains. Showing of gas, 9,746–9,771, acidized without results	9,783
32	Dolomite, very fine, crystalline, light brownish gray, somewhat siliceous, containing some rounded and frosted quartz grains	9,815
56	Dolomite, fine, crystalline, light brownish gray, containing a little fine quartz silt and sand; larger quartz grains rounded and frosted	9,871
4	Dolomite, fine, crystalline, brownish gray, somewhat siliceous, containing some very fine to fine quartz grains; larger grains rounded and frosted	9,875
15	Dolomite, fine, crystalline, brownish gray, containing considerable light gray oolitic chert, with individual siliceous oölites up to $1\frac{1}{4}$ millimeters in diameter	9,890
16	Dolomite, very fine to fine, crystalline, brownish gray, slightly argillaceous, containing some quartz silt and very fine sand, with most larger quartz grains rounded and frosted	9,906
57	Dolomite, very fine, crystalline, light brownish gray, containing a little white chert and some quartz silt and fine sand, with larger quartz grains rounded and frosted	9,963
85	Dolomite, fine to medium, crystalline, light brownish gray	10,048
	GATESBURG FORMATION, 48 FEET	
21	Limestone, fine crystalline, mottled light and dark gray, dolomitic, silty and sandy, with larger quartz grains rounded and frosted	10,069
5	Limestone, fine, crystalline, light brownish gray, dolomitic and sandy, with many quartz grains rounded and frosted	10,074
3	Sandstone, fine- to medium-grained, light gray, quartzose, dolomitic; many quartz grains rounded and frosted	10,077
7	Sandstone, fine-grained, light brownish gray, quartzose, very dolomitic; many quartz grains rounded and frosted	10,084
4	Sandstone, fine-grained, light gray, quartzose, slightly dolomitic; many quartz grains rounded and frosted	10,088
8	Sandstone, fine- to medium-grained, white; mostly angular quartz grains with some rounded and frosted. One bailer salt water per hour at 10,092 feet	10,096
	Total depth	10,096

STRATIGRAPHIC SECTIONS

Four series of stratigraphic sections, based on well-sample records and drillers' logs, have been assembled for the northern Appalachian basin, as follows.

Section *AA'* (Fig. 3) starts with Well 1 (Fig. 1), in the northwestern part of Ohio and extends south of lakes Erie and Ontario to Well 14 in south-central New York.

Section *BB'* (Fig. 4) starts with Well 15, west of Lake Ontario and extends south approximately along the 79th meridian to Butler County, Pennsylvania.

Section *CC'* (Fig. 5) starts with Well 5 in north-central Ohio and extends southeast and south approximately along the 82d meridian to the Ohio River.

Section *DD'* (Fig. 5) starts with Well 25 in central Ohio and extends east to Well 23, about halfway to the Pennsylvania line. The four sections are drawn on the top of the Trenton limestone as previously defined. This horizon does not coincide everywhere with the top of the Trenton group, as shown in Figure 2.

Source of Information for Stratigraphic Sections

Section AA'

No. 1.—Ohio Oil Company's Louis Barlage No. 1, Liberty Township, Putnam County, Ohio. Based on examination of drill cuttings by Chas. R. Fettke. Correlations in conformity with those of Cohee.[14]

No. 2.—J. E. Fennerty *et al.* D. L. Norris No. 1, Marion T., Hancock Co., Ohio. Based on examination of drill cuttings by D. D. Condit.[15] Correlations by Fettke. Condit placed strata between 729 and 1135 feet below top of Trenton in Lower Ordovician.

No. 3.—Ohio Oil Company's Bruns No. 1, Sandusky Co., Ohio. Based on examination of drill cuttings by Norval Ballard.[16] Correlations by Fettke. Ballard assigned interval between 633 and 991 feet below top of Trenton to Lower Ordovician.

No. 4.—C. W. White's Peter and Blanch Arting No. 1, Peru T., Huron Co., Ohio. Based on drillers' log. According to George D. Lindberg, oral communication, May 16, 1947, this well reached pre-Cambrian granite.

No. 5.—Ohio Oil Company's S. V. Krause No. 1, Ruggles T., Ashland Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 6.—Hanley and Bird's Grant W. Pitts No. 1, Pittsfield T., Lorain Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 7.—McCrea Oil and Gas Company *et al.* Billman No. 2, Spencer T., Medina Co., Ohio. Based on drillers' log.

No. 8.—East Ohio Gas Company's George W. Crile No. 1, Chardon T., Geauga Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 9.—Ohio Fuel Gas Company's George E. Chester No. 1, Rome T., Ashtabula Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 10.—Ohio Oil Company's Jay Childs No. 1, Springfield T., Erie Co., Pennsylvania. Based on examination of drill cuttings by Chas. R. Fettke.

No. 11.—Reservation Gas Company's George Button, Town of Collins, Erie Co., New York. Based on drillers' log. Reported to have been drilled 2 feet into granite.[17] Comparison with section obtained in Arcade well, 30 miles east, indicates dolomite probably mistaken for granite.

No. 12.—K. R. Wilson's Arcade No. 1, Town of Arcade, Wyoming Co., New York. Based on examination of drill cuttings by Chas. R. Fettke.

No. 13.—Reserve Oil Company's J. C. Mahaney No. 1, Town of Ledyard, Cayuga Co., New York. Based on examination of drill cuttings by Chas. R. Fettke.

No. 14.—Reserve Oil Company's Joe Farkas No. 1, Town of Lansing, Tomkins Co., New York. Based on examination of drill cuttings by Chas. R. Fettke.

Section BB'

No. 15.—Rockwood Oil and Gas Company's well, Lot 6, Con. IV, Eramosa T., Wellington Co., Ontario. Based on examination of drill cuttings by J. F. Caley.[18]

[14] George V. Cohee, "Sections and Maps of Lower Ordovician and Cambrian Rocks in the Michigan Basin, Michigan and Adjoining Areas," *U. S. Geol. Survey Prelim. Chart 9*, Oil and Gas Invest. Ser. (1945).

[15] D. D. Condit, "Deep Wells at Findlay, Ohio," *Amer. Jour. Sci.*, 4th Ser., Vol. 36 (1913), pp. 123–30.

[16] Norval Ballard, "Stratigraphy and Structural History of East-Central United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 11 (1938), pp. 1152–54.

[17] D. H. Newland and C. A. Hartnagel, "Review of the Natural Gas and Petroleum Developments in New York State," *New York State Mus. Bull. 295*, p. 122.

[18] J. F. Caley, "Paleozoic Geology of the Brantford Area, Ontario," *Canada Geol. Survey Mem. 226* (1941), pp. 90–91.

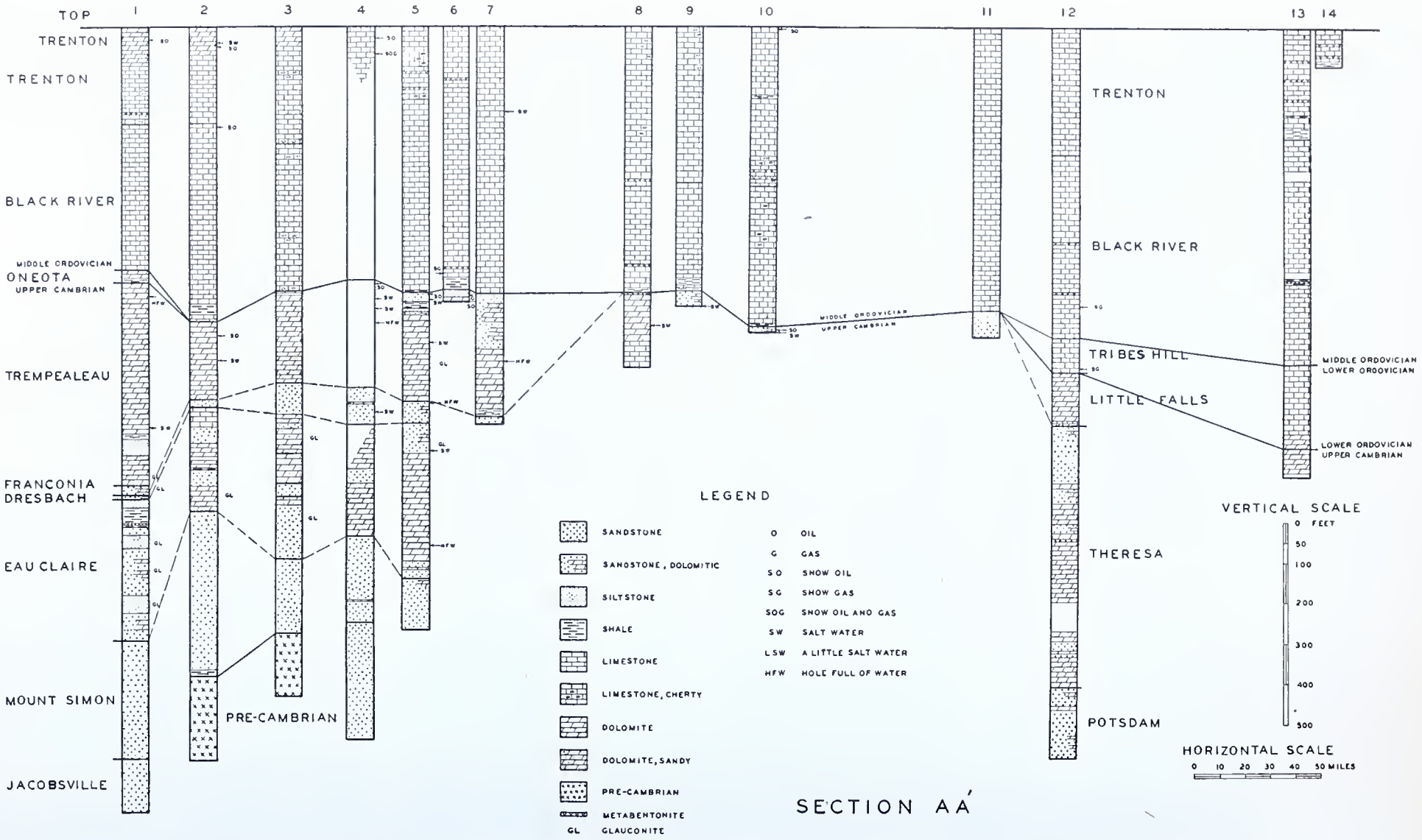


FIG. 3.—Stratigraphic section across northern part of Appalachian basin from northwestern Ohio to south-central New York.

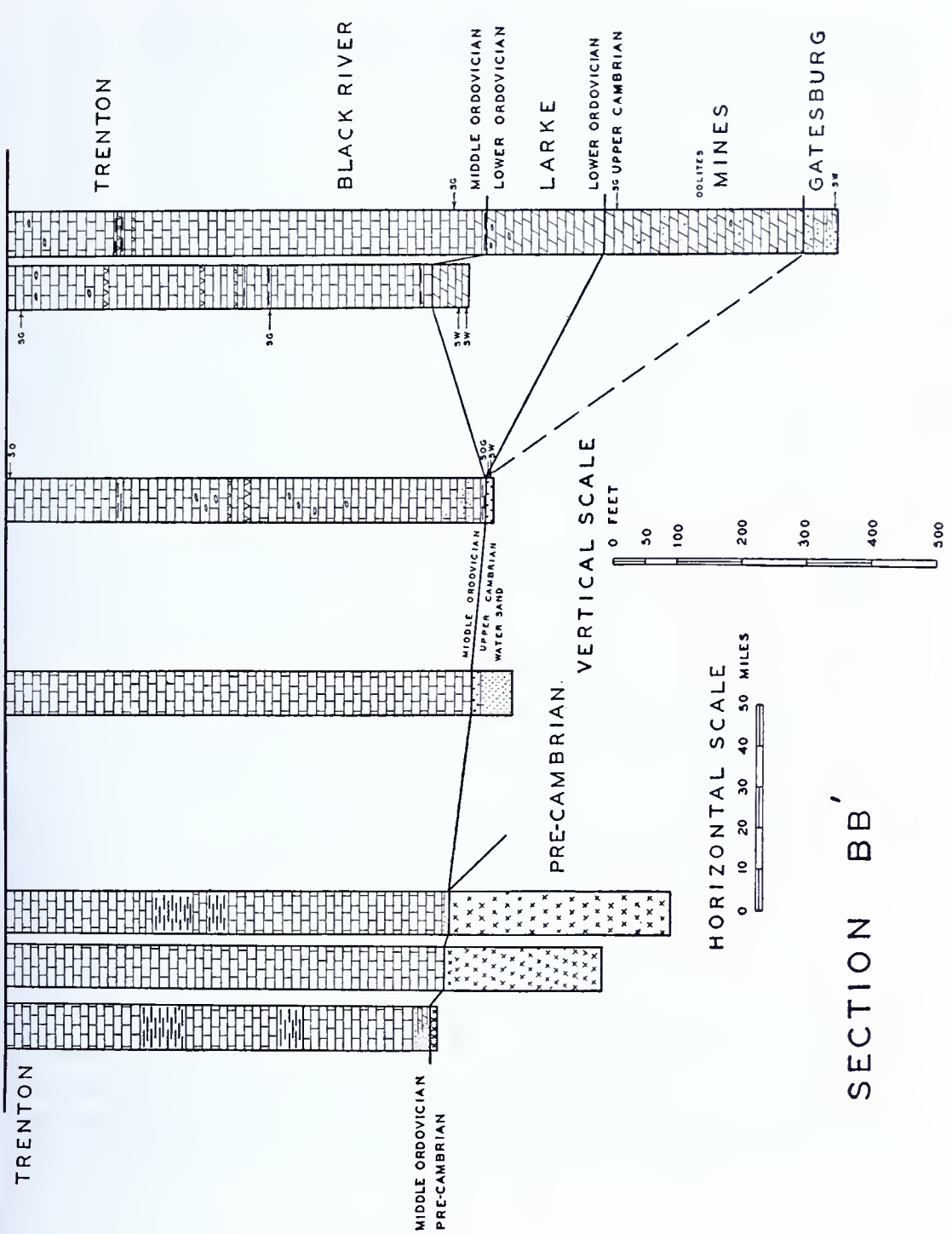


FIG. 4.—Stratigraphic section along 79th Meridian of Longitude.

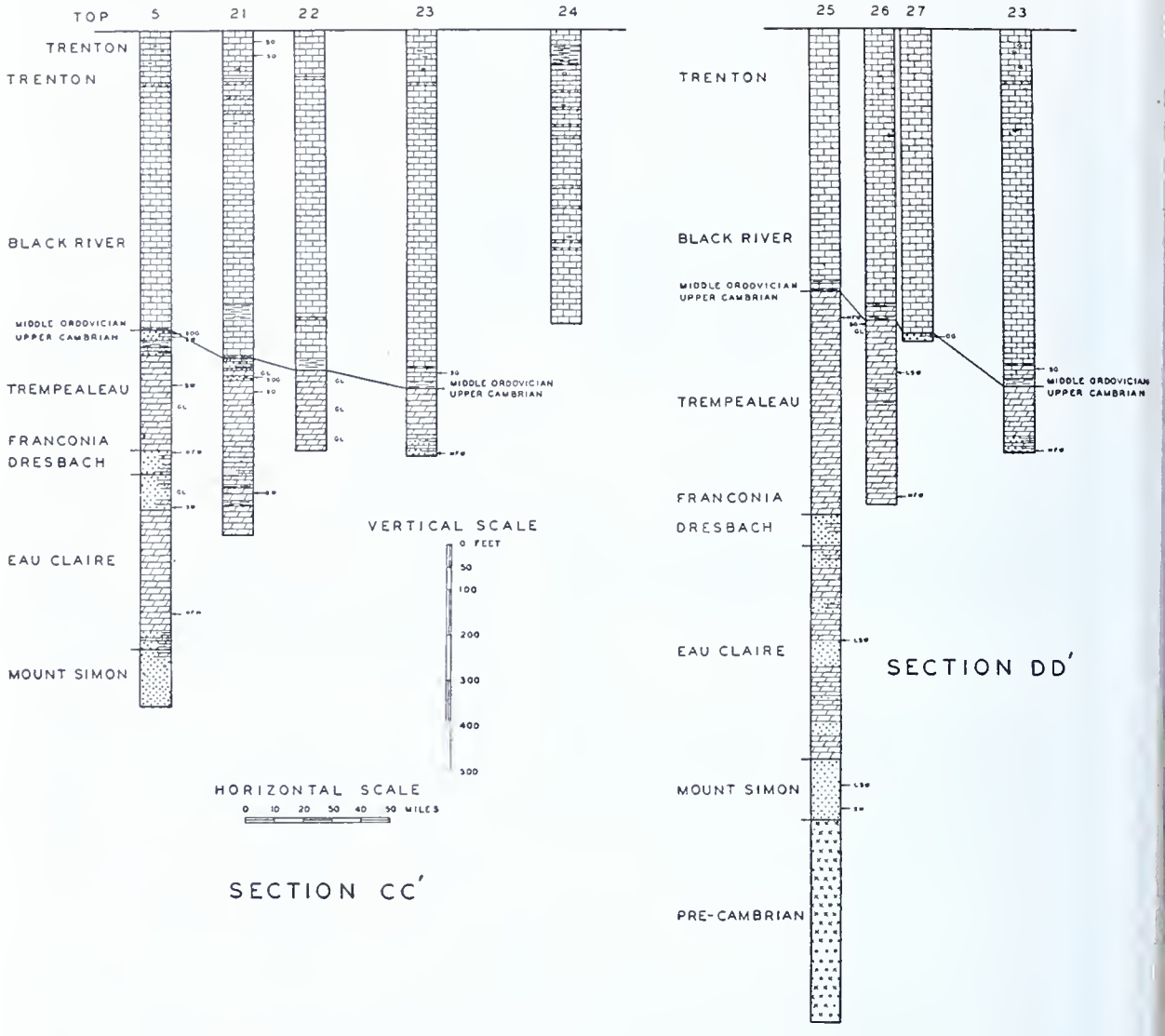


FIG. 5.—Stratigraphic sections along 82d Meridian of Longitude and across central Ohio.

No. 16.—Bollert Oil and Gas Comapny's well No. 1, Lot 7, Con. IV, Puslinch T., Wellington Co., Ontario. Based on examination of drill cuttings by J. F. Caley.[19]

No. 17.—Rockton Oil and Gas Company's well No. 3, Lot 30, Con. IV, Beverly T., Wentworth Co., Ontario. Based upon examination of drill cuttings by J. F. Caley.[20]

No. 18.—Dominion Natural Gas Company's Long Point, South Walsingham T., Norfolk Co., Ontario. Based on drillers' log. Harkness assigned bottom 50 feet, called water sand by drillers, to pre-Cambrian.[21] Recent exploration on opposite side of Lake Erie in northwestern Pennsylvania and western New York makes it appear doubtful that well reached pre-Cambrian.

No. 10.—Ohio Oil Company's Jay Childs No. 1.

[19] J. F. Caley, "Paleozoic Geology of the Toronto-Hamilton Area, Ontario," *ibid., Mem. 224* (1940), pp. 137–38.

[20] *Ibid.*, pp. 127–28.

[21] R. B. Harkness, "Gas and Oil in Eastern Ontario," *Ontario Bur. Mines, 46th Ann. Rept.*, Vol. 46, Pt. 5 (1937), cross section opp. p. 102.

No. 19.—United Natural Gas Company's Maude Davidson No. 1, Worth T., Mercer Co., Pennsylvania. Based on examination of drill cuttings by Chas. R. Fettke.

No. 20.—Manufacturers Light and Heat Company's Jessie G. Hockenberry No. 1, Mercer T., Butler Co., Pennsylvania. Based on examination of drill cuttings by Chas. R. Fettke. Total depth 10,096 feet; deepest well in Appalachian basin; deepest well drilled entirely with cable tools.

SECTION CC′

No. 5.—Ohio Oil Company's S. V. Krause No. 1.

No. 21.—Ohio Oil Company's J. H. Armstrong No. 8, Wooster T., Wayne Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 22.—Ohio Oil Company's Chaney-Meyer, Unit 2, No. 1, Clark T., Coshocton Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 23.—Industrial Gas Corporation's Sidney Whitmire No. 1, Salt Creek T., Muskingum Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

No. 24.—Sinclair Prairie Oil Company's George Longsworth No. 1, Olive T., Meigs Co., Ohio. Based on examination of drill cuttings by Chas. R. Fettke.

SECTION DD′

No. 25.—Chester L. Wise *et al.*, Herman E. Vance No. 1, Orange T., Delaware Co., Ohio. Based on examination of drill cuttings by Wilber Stout and Carl A. Lamey.[22] Correlations by Fettke. Stout and Lamey assigned the interval between 579 and 1030 feet below top of Trenton to Lower Ordovician.

No. 26.—S. D. and W. B. McCloy's Bertha Rowe No. 1, Jersey T., Licking Co., Ohio. Based on drillers' log.

No. 27.—W. W. and A. T. Wehrle No. 8, Newark T., Licking Co., Ohio. Based on drillers' log.

No. 23.—Industrial Gas Corporation's Sidney Whitmire No. 1.

CORRELATION

Wells in the northern part of the Appalachian basin that have reached the pre-Cambrian are confined to the margins of the basin. A number have been completed along the Cincinnati arch and its northwest fork, the Findlay arch. Of these, the Vance well, No. 25, in central Ohio is located on the western flank of the basin and farthest from the arch. Wells have also been drilled to the pre-Cambrian along the northern and northeastern rims of the basin in southern Ontario and on the southwest side of the Adirondack Mountains. Data on the total thickness and nature of the Lower Ordovician and the Cambrian rocks over most of the basin are lacking.

Along the northern margin of the basin in southern Ontario, Middle Ordovician limestones overlap the Cambrian and rest directly on the pre-Cambrian so that outcrop sections and marginal wells give no clue as to what may be present out in the basin. Along the southwest flank of the Adirondack Mountains, as pointed out by Ulrich and Cushing,[23] numerous gaps occur in the exposed sections of the Ordovician and Cambrian strata and the outcrop sections are relatively thin and imperfect. These conditions make it difficult to correlate the limited sections of pre-Middle Ordovician rocks that have been penetrated by wells in the basin.

[22] Wilber Stout and Carl A. Lamey, "Paleozoic and Pre-Cambrian Rocks of Vance Well, Delaware County, Ohio," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 4 (1940), pp. 672–92.

[23] E. O. Ulrich and H. P. Cushing, "Age and Relation of the Little Falls Dolomite (Calciferous) of the Mohawk Valley," *New York State Mus. Bull. 140* (1920), p. 137.

UPPER CAMBRIAN OR CROIXIAN SERIES

Cohee[24] has carried the subsurface correlation of the Trenton and sub-Trenton rocks from their outcrops around the western and southern margins of the Michigan basin to the Barlage well in northwestern Ohio (No. 1 on map, Fig. 1). The writer has accepted Cohee's interpretation of the section exhibited by the Barlage well and has extended the correlation across the northern part of the Appalachian basin to join to the extent that present exploration permits, the outcrops on the southwest flank of the Adirondack Mountains and in central Pennsylvania.

Altogether, 1314 feet of strata are assigned to the Upper Cambrian in the Barlage well. The lower 135 feet consist of grayish red, somewhat argillaceous sandstone with grayish red arkose at the base. This interval is correlated questionably with the Jacobsville sandstone of the northern peninsula of Michigan.[25] Cohee interprets the basal arkose as representing weathered pre-Cambrian granite. The Jacobsville sandstone is reported to be Upper Cambrian in age but this has not been established definitely. A similar sandstone was recognized by Wasson[26] in the Friend well, No. 29, Clark County, Ohio, in the interval from 3330 to 3419 feet. It was not encountered in the Vance well,[27] No. 25, in central Ohio.

Of the remaining 1179 feet of Upper Cambrian beds in the Barlage well, 292 feet are assigned to the Mt. Simon sandstone; 350 feet to the Eau Claire sandstone; 10 feet to the Dresbach sandstone; 25 feet to the Franconia sandstone; and 502 to the Trempealeau formation, in ascending order.

The Mt. Simon sandstone in the Barlage well consists of fine- to coarse-grained, light gray, quartzose sandstone, becoming light reddish gray toward the base. The Krause well, No. 5, had penetrated 126 feet of similar sandstone at the time that drilling was stopped. The 176 feet of sandstone assigned to the Potsdam at the bottom of the Arcade well, No. 12, are believed to occupy approximately the stratigraphic position of the Mt. Simon in the western wells.

The Eau Claire in the Barlage well consists predominantly of very fine- to medium-grained, somewhat dolomitic sandstone, but considerable dolomitic siltstone and a little shale are also present. Glauconite occurs in both the sandstone and the siltstone. In the Krause well, the Eau Claire is considerably more dolomitic and glauconite is only here and there present. In the Arcade well, the dolomitic part of the interval assigned to the Theresa, below the upper sandstone, probably corresponds in age with the Eau Claire.

[24] George V. Cohee, "Sections and Maps of Lower Ordovician and Cambrian Rocks in the Michigan Basin, Michigan and Adjoining Areas," *U. S. Geol. Survey Prelim. Chart 9*, Oil and Gas Invest. Ser. (1945).

[25] George V. Cohee, *op. cit.*

[26] Isabel B. Wasson, "Sub-Trenton Formations in Ohio," *Jour. Geology*, Vol. 40, No. 8 (1932), p. 686.

[27] Wilber Stout and Carl A. Lamey, "Paleozoic and Pre-Cambrian Rocks of Vance Well, Delaware County, Ohio," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 4 (1940), p. 687.

Ten feet of fine- to medium-grained brownish gray, somewhat dolomitic sandstone free from glauconite probably represent the Dresbach sandstone in the Barlage well. Both the overlying sandstone and the underlying siltstone contain glauconite. By definition, the Dresbach (Galesville) is free from glauconite or fossils.[28] In the Krause well, the Dresbach is represented by 57 feet of sandstone. The 141 feet of sandstone comprising the upper part of the interval assigned to the Theresa in the Arcade well and the lower 22 feet of sandstone of the 48 feet of strata allocated to the Gatesburg formation at the bottom of of the Hockenberry well, No. 20, occur approximately at the horizon of the Dresbach sandstone. The bottom 12 feet of sandstone in the Childs well, No. 10, originally correlated with the St. Peter,[29] are now thought to represent the Dresbach.

The Franconia sandstone as recognized in the Barlage well consists of 25 feet of fine- to medium-grained brownish gray dolomitic sandstone containing a little glauconite. This sandstone was not recognized as a distinct unit in any of the wells in central Ohio from which drill-cutting samples were examined.

The Trempealeau formation in the Barlage well consists largely of very fine, crystalline, relatively pure dolomite with minor amounts of interbedded dolomitic siltstone and shale. The dolomite becomes sandy and contains a little glauconite in its lower part. The Trempealeau contains more silt and sand in the Krause and other wells in central Ohio. No chert was observed in it in Ohio. In the Arcade and Mahaney wells, the interval assigned to the Little Falls dolomite is believed to be correlative with the Trempealeau and in the Hockenberry well the interval assigned to the Mines dolomite occupies approximately the same position.

The Trempealeau formation on the outcrop in Wisconsin,[30] in ascending order, consists of basal greensand and conglomerate, succeeded by dolomite, dolomitic siltstone, and fine-grained thin-bedded sandstones grading upward into massively bedded and coarser-grained sandstones. Fossils occur throughout the formation. The total thickness ranges from 60 to 175 feet in different sections. Cohee[31] has traced the Trempealeau in the subsurface around the western and southern margins of the Michigan basin and finds that it thickens to 700 feet in northern Indiana and to more than 500 feet in southeastern Michigan. It becomes predominantly a dolomite but retains its somewhat sandy nature in parts. Minor amounts of interbedded shaly dolomite and dolomitic shale occur in it.

[28] W. H. Twenhofel, G. O. Raasch, and F. T. Thwaites, "Cambrian Strata of Wisconsin," *Bull. Geol. Soc. America*, Vol. 46 (1935), p. 1697.

[29] Chas. R. Fettke, "Subsurface Sections Across Western Pennsylvania," *Pennsylvania Topog. and Geol. Survey Prog. Rept. 127* (1941), p. 6.

[30] W. H. Twenhofel, G. O. Raasch, and F. T. Thwaites, "Cambrian Strata of Wisconsin," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 1705–12.

[31] George V. Cohee, "Sections and Maps of Lower Ordovician and Cambrian Rocks in the Michigan Basin, Michigan and Adjoining Areas," *U. S. Geol. Survey Prelim. Chart 9*, Oil and Gas Inves. Ser.

The 176 feet of very fine- to fine-grained, light gray to light brownish gray sandstone at the bottom of the Arcade well are thought to represent the Potsdam sandstone of the Adirondack region. The sandstone in the Arcade well possesses a finer texture than typical Potsdam sandstone but this may be accounted for by the fact that it was deposited farther from the source of the sand. Much of it is dolomitic. Considerable salt water was encountered about 70 feet below its top. The stratigraphic position of this sandstone corresponds with that of the Warrior limestone in central Pennsylvania.

The succession of interbedded, very fine, crystalline, brownish gray, sandy and silty dolomites and fine- to medium-grained light brownish gray sandstones that overlie the basal sandstone in the Arcade well are correlated with the Theresa formation of the northwestern Adirondacks, but the thickness is considerably greater, 643 feet as compared with a maximum of about 120 feet on the outcrop. The lithologic character of these beds is similar to that of the Gatesburg formation of central Pennsylvania. The 141 feet of sandstone, constituting the upper part, are believed to have the same stratigraphic position as the Dresbach sandstone in the western sections. A little salt water was encountered in the middle of this sandstone in the Arcade well. The bottom 48 feet of dolomitic sandy limestone and fine- to medium-grained light gray quartzose sandstone in the Hockenberry well are correlated with the Gatesburg formation of central Pennsylvania. The sandstone in which drilling was stopped when salt water was encountered appears to correspond in stratigraphic position with the Dresbach sandstone of the wells at the west.

The 130 feet of strata in the Arcade well and 68 feet in the Mahaney well, No. 13, that consist predominantly of fine, crystalline, light gray to light brownish gray dolomite, somewhat sandy and silty in part, have been correlated with the Little Falls dolomite of the New York section. No chert was observed in this dolomite. The lithologic character is very similar to that of the Trempealeau. In the Hockenberry well, 308 feet of only slightly sandy, fine, crystalline, brownish gray dolomite are correlated with the Mines dolomite of central Pennsylvania. A little chert is present in some of the beds comprising the interval and about 135 feet from the top, 15 feet of the dolomite contain considerable quantities of light gray siliceous oölites. The Mines dolomite on the outcrop in central Pennsylvania contains abundant chert. Siliceous oölites are common in it, but these are usually black in color instead of light gray. The Hockenberry is the only well in which any chert was observed in strata in the well sections that are correlated with the Trempealeau.

LOWER ORDOVICIAN OR CANADIAN SERIES

Thirty-three feet of very fine, crystalline, light brownish gray dolomite and light greenish gray dolomitic shale and siltstone have been questionably assigned to the Oneota in the Barlage well. Lower Ordovician strata were not recognized

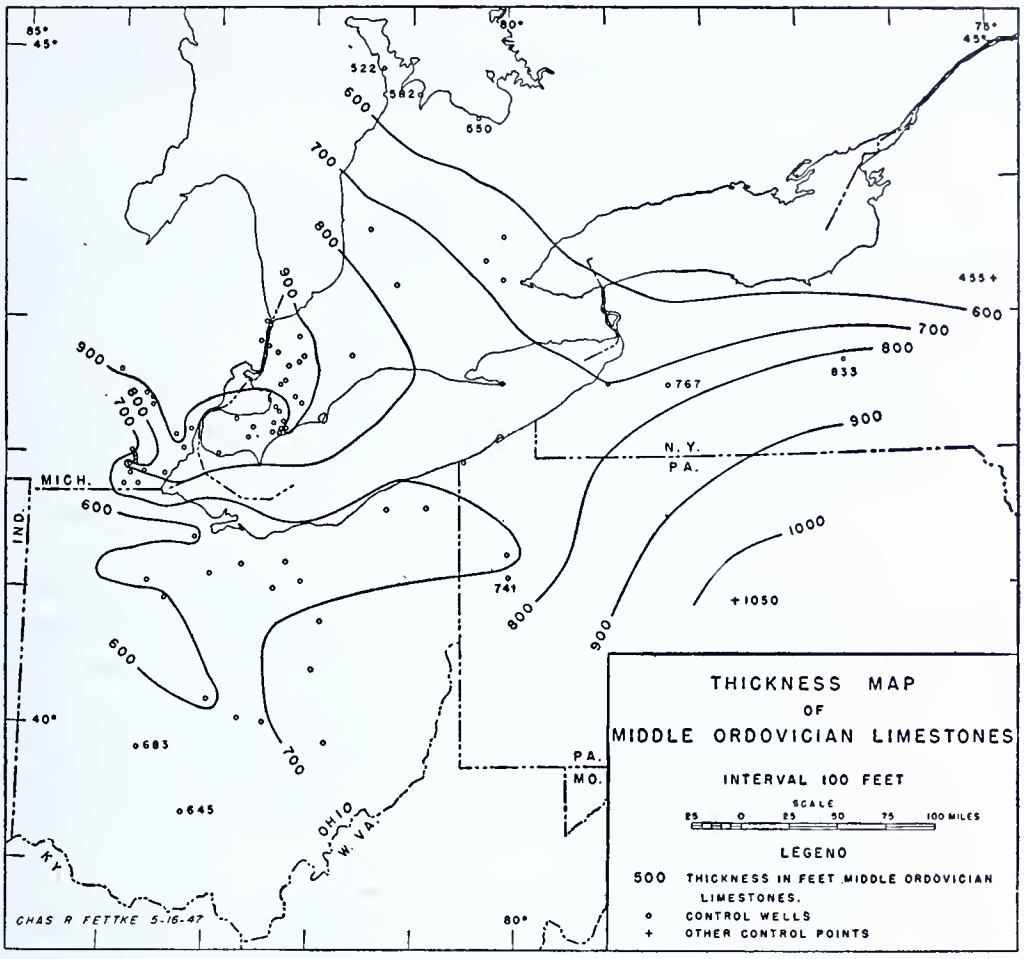


FIG. 6.—Thickness map of Middle Ordovician limestones in northern part of Appalachian basin.

in any of the wells in central Ohio. In south-central Ohio in the Walter Pierre well, No. 28, the lower 60 feet of section consists of very fine, crystalline, light gray, sandy dolomite containing a little light gray chert that may belong to the Oneota.

In the Hockenberry well in western Pennsylvania, 187 feet of relatively pure, fine, crystalline, light brownish gray dolomite containing almost no quartz grains and only a little light gray chert are correlated with the Larke dolomite of central Pennsylvania. Here and there, minute vugs, lined with tiny dolomite crystals, are present in this dolomite. Similar, but larger vugs, were observed in the outcrop of the Larke dolomite east of Williamsburg in central Pennsylvania.

The Tribes Hill limestone of the New York section and its equivalent, the Stonehenge limestone of central Pennsylvania, are believed to be represented by 86 feet of limestone in the Arcade well and 211 feet in the Mahaney well. The

limestones comprising this interval are fine in texture and argillaceous and magnesian in composition. They contain a few rounded and subrounded, frosted quartz grains. Some beds contain calcareous oölites.

MIDDLE ORDOVICIAN OR CHAMPLAINIAN SERIES

Middle Ordovician or Champlainian limestones underlie the entire Appalachian basin. Their thickness is shown on the map (Fig. 6). In the northern part of the basin, strata of Chazy age are probably confined to the eastern margin. In central Pennsylvania the Chazy is represented by 200 or more feet of strata which Kay has subdivided into the Loysburg and Hatter formations, in ascending order,[32] Butts included these in his Carlim limestone.[33] Strata of Chazy age are absent on the outcrop on the southwest side of the Adirondack Mountains and north of Lake Ontario.[34] None was recognized in the well sections in central and western New York, western Pennsylvania, and central and north-central Ohio.

Mohawkian limestones, comprising the Black River and Trenton groups of the Middle Ordovician, are present over the entire Appalachian basin. Stratigraphers and paleontologists are not yet in complete agreement about the correlation of the various formations and members that these two groups have been divided into on the outcrop around the margins of the basin. No attempt, therefore, has been made to separate the two groups in the well sections. Drillers commonly log this entire series of limestones under the term Trenton in the northern Appalachian area.

The Mohawkian limestones range in composition from argillaceous to almost pure limestone and in texture, from very fine, crystalline, to lithographic. In general, the upper part of the series is more argillaceous than the middle and lower parts and also more fossiliferous. Dolomites and dolomitic limestones are practically absent. Minor amounts of chert are present at certain horizons. Although shaly limestones are fairly common, true shales make up only a very small part of the section. In central and north-central Ohio, 5 or more feet of grayish green, calcareous shales, in part silty, commonly occur at what is believed to be the base of the Black River group. Thin beds of limestone, in places dolomitic, are in places interstratified with the shale and commonly contain some rounded and frosted quartz grains.

Bentonites occur as thin layers in the Black River and Trenton. The writer has observed them in most of the well sections in the northern part of the Appa-

[32] G. Marshall Kay, "Middle Ordovician of Central Pennsylvania," *Jour. Geology*, Vol. 52 (1944), pp. 3–15.

[33] Charles Butts, Geologic Section of Blair and Huntingdon Counties, Central Pennsylvania," *Amer. Jour. Sci.*, 4th Ser., Vol. 46 (1918), p. 526.

[34] H. P. Cushing, "Nomenclature of the Lower Paleozoic Rocks of New York," *Amer. Jour. Sci.*, Ser. 4, Vol. 31 (1911), p. 138.
G. Marshall Kay, "Ottawa-Bonnechere Graben and Lake Ontario Homocline," *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 591.

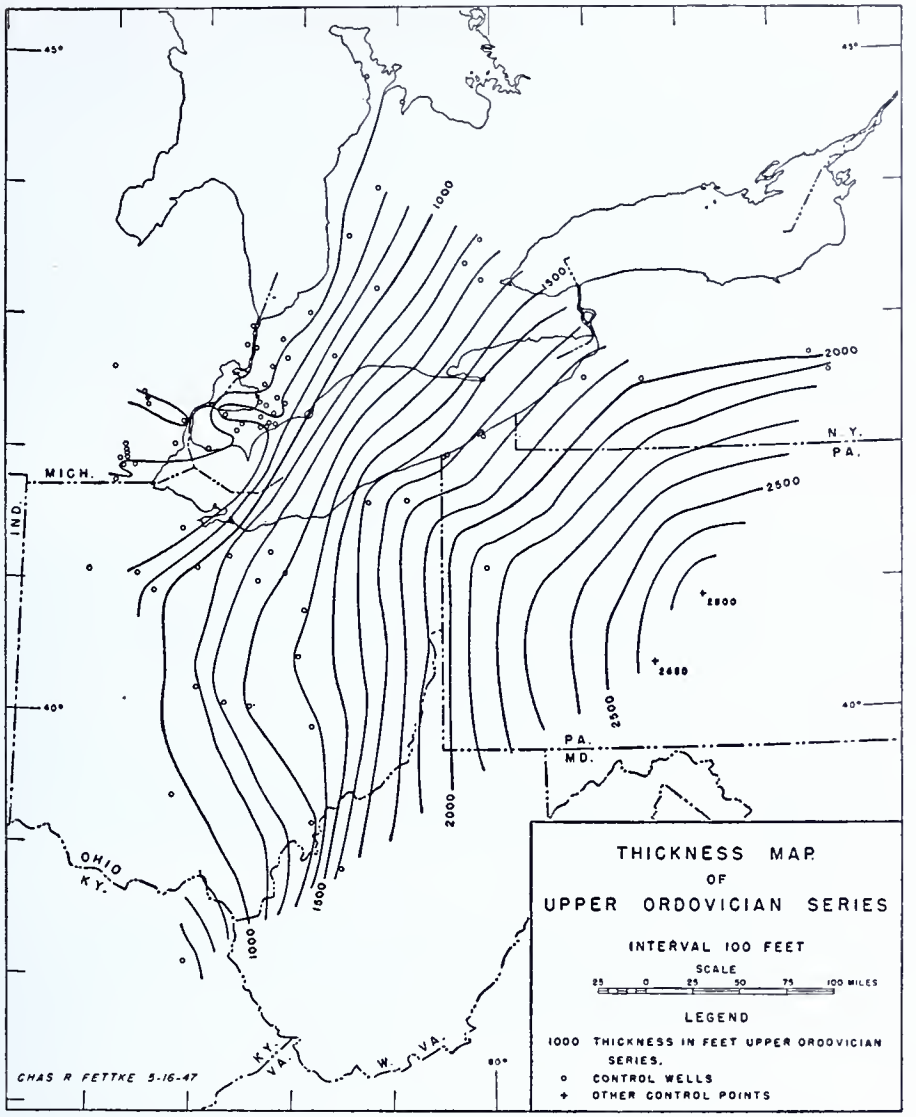


FIG. 7.—Thickness map of Upper Ordovician series in northern part of Appalachian basin.

lachian basin from which samples were available and others have described them from many localities on the outcrop.[35] In central Pennsylvania the lowest bentonite bed recognized thus far occurs in the upper part of the Stover limestone of

[35] C. A. Bonine and A. P. Honess, "Bentonites in Pennsylvania," *Pennsylvania Acad. Sci.*, Vol. 3 (1929), pp. 18–25.

Victor T. Allen, "Ordovician Altered Volcanic Material in Iowa, Wisconsin, and Missouri," *Jour. Geology*, Vol. 40 (1932), pp. 259–69.

Laurence Whitcomb, "Correlation by Ordovician Bentonite," *ibid.*, Vol. 42 (1932), pp. 522–34.

G. Marshall Kay, "Distribution of Ordovician Altered Volcanic Materials and Related Clays," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 225–44.

Laurence Whitcomb and R. R. Rosenkrans, "Bentonite Beds in the Lower Chambersburg," *ibid.*, pp. 1251–54.

Arthur C. McFarlan, "Geology of Kentucky," *Univ. Kentucky* (1943), pp. 12–13.

the Black River group. Five beds are distributed through the Valley View limestone of the Black River. Two occur in the upper part of the Oak Hall limestone and seven or more in the Salona limestone of the Trenton group. In Tennessee, Fox and Grant have also found a bentonite bed in the Chazy and one in the lower part of Sequatchie formation of the late Upper Ordovician.[36] As more well-sample sections became available in the Appalachian basin, the bentonites undoubtedly will be valuable horizon-markers, not only for local but also for regional correlation. For example, the two bentonites in the upper part of the Oak Hall member of the Nealmont limestone in central Pennsylvania are probably the equivalent of the "Pencil Cave" and the "Mud Cave" bentonites which occur in the upper part of the Tyrone limestone in central Kentucky.[37]

UNCONFORMITY AT BASE OF MIDDLE ORDOVICIAN

In the northern part of the Appalachian basin, the most prominent unconformity in the Lower Paleozoic section occurs at the base of the Middle Ordovician. In the Arcade and Mahaney wells in south-central New York, the Black River limestone of the Middle Ordovician rests on the Tribes Hill limestone, the basal formation of the Lower Ordovician. All of the Chazy and most of the Beekmantown are missing. The exposed section on the southwest flank of the Adirondack Mountains, as has been pointed out, is very incomplete. Black River limestones, locally, rest on the Little Falls, the Theresa formation, the Potsdam sandstone, or the pre-Cambrian.

North of Lake Ontario the Black River rests on the pre-Cambrian.

In western Pennsylvania in the Hockenberry well the Black River limestone overlies what is probably a basal Lower Ordovician dolomite. All of the Chazy and most of the Beekmantown are missing, as in the Arcade and Mahaney wells. In central Pennsylvania in the vicinity of Bellefonte, 120 miles east of the Hockenberry well, this interval is represented by approximately 4500 feet of strata. There is no sharp lithologic break between the Chazy limestone of the Middle Ordovician which underlies the Black River limestone in central Pennsylvania and the Bellefonte dolomite of the Lower Ordovician. Possibly, as Kay has suggested,[38] the sandstone present in the upper part of the Bellefonte dolomite, south of Bellefonte, may occur at this boundary. The horizon of this sandstone is about 500 feet below the top of the Bellefonte dolomite at Bellefonte, but is scarcely recognizable there. The member has its best development about 5

[36] P. P. Fox and L. F. Grant, "Ordovician Bentonites in Tennessee and Adjacent States," *Jour. Geol.*, Vol. 52 (1944), pp. 319–32.

[37] G. Marshall Kay, oral communication, May 31, 1946.

[38] G. Marshall Kay, "Middle Ordovician of Central Pennsylvania," *Jour. Geol.*, Vol. 52 (1944), pp. 5–6.

miles south in the vicinity of Dale Summit where it has a thickness of 15 feet and forms a distinct ridge.[39]

It is believed that the sandstone encountered at 10,074 feet in the Hockenberry well, No. 20, is the equivalent of the one that occurs at 5179 feet in the Childs well, No. 10. The regional unconformity, apparently, cuts out 520 feet of strata in a distance of 65 miles in a slightly west-of-north direction in northwestern Pennsylvania. Similarly, if the two sandstones identified as Dresbach in the Vance No. 25, and the Krause No. 5, respectively, in central Ohio have been correctly correlated, the thickness of the combined Trempealeau and Franconia formations has been reduced by 225 feet in a distance of 65 miles in a northeast direction.

In central Ohio, as far south as the Vance No. 25, and the Whitmire No. 23, Black River limestone appears to rest on Trempealeau dolomites and dolomitic sandstones and siltstones. Beekmantown and Chazy strata apparently are absent. Early Beekmantown dolomites are encountered in wells on the west, south, and east. North and northeast, in southwestern Ontario and northeastern Ohio, the Black River limestone successively overlaps the beveled edges of older and older Upper Cambrian formations until finally it comes to rest on the pre-Cambrian.[40]

The Appalachian basin was submerged during most of Upper Cambrian time. The clastic parts of the Upper Cambrian sediments in the northern part of the basin were derived from low-lands on the north. During early Ordovician time a very broad and low southward-plunging arch developed, which extended into central Ohio from southwestern Ontario in the form of a low peninsula a little east of the present Findlay arch. Beekmantown dolomites continued to accumulate in adjacent seas while over the arch the Upper Cambrian strata were exposed to weathering and underwent a moderate amount of erosion. Later, Black River limestones were deposited unconformably over the older strata.

STRUCTURE

The Appalachian basin is a broad asymmetrical and complex structural trough or synclinorium whose long axis trends northeast and southwest, with the steep limb on the southeast side. On the southeast (Figure 1) it is bounded by closely folded Appalachians, on the northeast by the Adirondack Mountains and the Frontenac arch, on the north by the pre-Cambrian highlands of central Ontario, on the northwest by the Findlay-Algonquin arch, and on the west by the Cincinnati arch. Many of the formations of the basin extend considerable distances beyond the limits of the present structural trough.

[39] Charles Butts and Elwood S. Moore, "Geology and Mineral Resources of the Bellefonte Quadrangle, Pennsylvania," *U. S. Geol. Survey Bull. 855* (1936), pp. 30–31.

[40] George V. Cohee, "Cambrian and Ordovician Rocks in Recent Wells in Southeastern Michigan," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31 (1947), pp. 303–5.

The regional structure of the northern part of the basin is shown in Figure 1 by means of contours drawn on the top of the Trenton limestone. Only the northwestern flank is included. The data for southeastern Michigan and adjacent parts of southwestern Ontario were taken from a map published by Cohee[41] and for the northern part of western New York, from one by Hartnagel.[42] The rest of the map is based on drillers' logs and well-sample records. In areas where wells have not reached the Trenton, the contours are shown as broken lines. In these areas the intervals from the deepest horizons penetrated by wells and the top of the Trenton were estimated by assuming that the rate of change in thicknesses of the formations involved is uniform between the nearest Trenton wells and the outcrop sections.

It will be noted in Figure 1 that the deepest part of the basin on top of the Trenton limestone is located very close to the Appalachian structural front. In Clearfield County, central Pennsylvania, it is estimated that the top of the Trenton limestone is approximately 11,000 feet below sea-level, whereas, less than 25 miles southeast the limestone crops out at elevations of 1100–1500 feet above sea-level. With respect to the surface beds, on the other hand, the central part of the basin is located in southeast Ohio, southeast Pennsylvania, and northwest West Virginia, where it is floored with beds of Permian age. The shift in the axis with depth is due in considerable part to the southeastward thickening of the great series of clastic deposits constituting the Upper Ordovician, Silurian, and Upper Devonian, respectively, particularly the last.[43] The thickness of the Upper Ordovician series is shown in Figure 7.

The regional structure of the basin is modified by a series of minor folds with axes trending approximately parallel with the long axis of the basin. On the southeast side these consist of strong, well defined anticlines and synclines, but northwestward the intensity of folding diminishes so that the folds become less prominent in the central part of the basin and disappear in the northwest part. The Chestnut Ridge anticline (Fig. 1) is the westernmost of the more prominent folds. Deep drilling for Oriskany gas has revealed that these folds are much more complex structurally than had been anticipated from the earlier surface mapping. It has been found that extensive, commonly northwest-dipping, reverse faults intersect and complexly modify the outlines of the more prominent domes along the anticlinal axes at the Oriskany horizon. Vertical separations of as much as 850 feet have been encountered at this horizon. Although some of the faults have been recognized on the outcrop, no displacements of this magnitude have been observed.

[41] George V. Cohee, *op. cit.*

[42] Chris A. Hartnagel, "The Medina and Trenton of Western New York," *ibid.*, Vol. 22 (1938), p. 90.

[43] Chas. R. Fettke, "Subsurface Studies in Connection with Deep Oil and Gas Sand Explorations in Pennsylvania," *Pennsylvania State College, School of Mineral Indus. Exp. Sta. Bull. 30* (1940), p. 41.

The synclinorium which constitutes the Appalachian basin of today came into existence during the Appalachian revolution at the close of the Paleozoic era. It was at this time that its southeastern rim was established. However, many of the prominent structural features of the basin antedate that revolution and later earth movements have produced some modifications.

OIL AND GAS POSSIBILITIES

The Trenton and sub-Trenton rocks have yielded a little oil and a small amount of gas in the Appalachian basin. Although the quantities have been almost negligible, the occurrences have demonstrated that the rocks do contain oil and gas in places. Inasmuch as only a small part of the area can be considered to be adequately tested, it seems probable that there are areas where conditions existed in these rocks that were favorable for the accumulation of larger deposits. The Trenton and sub-Trenton rocks of the Appalachian basin can be considered to offer definite possibilities as potential sources of gas and oil.

TRENTON

The Trenton has been an important source of both oil and gas along the Findlay arch which borders the Appalachian basin on the northwest. Cohee estimates that 479,000,000 barrels of oil have been obtained from 577,000 acres in the Lima-Indiana field.[44] The oil has been produced chiefly from the upper 50 feet of the Trenton and commonly from the upper 25 feet, but some has come from lower levels, 100–300 feet below the top of the limestone. The oil does not occur at any definite horizon.

Orton early recognized that the accumulation of oil in commercial quantities in the Trenton limestone in the Lima-Indiana field was confined to areas where the limestone had undergone local dolomitization.[45] Carman and Stout state that a magnesium carbonate content of at least 20 per cent is necessary for production and the best production is found where the rock is a true dolomite.[46] Landes has recently advanced the theory that local diastrophism produced master fissures in the limestone-containing section; that an artesian circulation developed which carried waters through deeper dolomites and up into the limestone; and that these waters replaced some of the limestone by dolomite that is locally porous where there was an excess of solution over precipitation during the replacement process.[47]

[44] George V. Cohee, "Geology and Oil and Gas Possibilities of Trenton and Black River Limestones of the Michigan Basin, Michigan and Adjacent Areas," *U. S. Geol. Survey Prelim. Chart 11*, Oil and Gas Inves. Ser. (1945).

[45] Edward Orton, "The Trenton Limestone as a Source of Oil and Gas in Ohio," *Geol. Survey Ohio*, Vol. VI (1888), pp. 307–8.

[46] J. Ernest Carman and Wilber Stout, "Relationship of Accumulation of Oil to Structure and Porosity in the Lima-Indiana Field," *Problems of Petroleum Geology*, Amer. Assoc. Petrol. Geol. (1934), p. 528.

[47] Kenneth K. Landes, "Porosity Through Dolomitization," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30 (1946), pp. 305–18.

Six shallow gas pools have been opened in the Trenton on the southwest side of the Adirondack Mountains at the east end of Lake Ontario in New York (Fig. 1). The earliest discoveries were made 60 years ago. None of the pools has been large, but some have been long-lived. The output has been consumed locally. According to Hartnagel, the limestone beds are not dolomitic and they do not possess sufficient porosity to serve as reservoir rocks. The gas is found in cavities, seams and joints in shale partings and shale beds and in the limestone itself. Coral reefs within the Trenton are also believed to serve as a source of some of the gas. The gas does not occur at any definite horizon. In a single well, gas may be found at as many as 20 horizons distributed through the entire thickness of the formation.[48]

The recent discovery of oil in commercial quantities in the Trenton limestone on the Powell Valley anticline at Rose Hill in the southwest corner of Virginia is encouraging. It reveals that locally the early Paleozoic rocks still retain some oil, even east of the structural front where they have undergone considerable deformation. According to Miller and Fuller, the oil in the Trenton at Rose Hill does not occur in pore spaces inherent in the original rock or in open spaces that have been induced by dolomitization of the limestone. The oil is probably present in small fractures formed by the shattering of the rock during the period of folding and overthrusting. The oil is not confined to a single stratigraphic zone in the Trenton, and wells only a few hundred feet apart produce from widely separated zones. One well has produced oil from a limestone below the Trenton.[49]

Considerable exploratory drilling has been conducted in the Trenton limestone in northwestern New York and central Ohio where the limestone is relatively shallow. Results have been disappointing. No areas of local dolomitization in the Trenton limestone similar to the occurrence along the Findlay arch in northwestern Ohio and adjacent parts of Indiana have been discovered. Where the Trenton rocks outcrop in central Pennsylvania there is no evidence of local dolomitization along major anticlinal folds.

There is a possibility, however, that the Trenton limestone may have undergone sufficient fracturing along the crests of some of the stronger anticlines in the eastern part of the Appalachian basin to act as a reservoir rock for the accumulation of oil and gas. Unfortunately, as shown in Figure 1, the Trenton limestone is so deeply buried under these structures that it is questionable whether its exploration at present is economically feasible. There is one locality, however, in the vicinity of Schellsburg, Bedford County, in south-central Pennsylvania where the depth is not prohibitive. In this area, the belt between the

[48] Chris A. Hartnagel, "The Medina and Trenton of Western New York," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 88–99.

[49] Ralph L. Miller and J. Osborn Fuller, "Geologic and Structure Contour Maps of the Rose Hill Oil Field, Lee County, Virginia," *U. S. Geol. Survey Prelim. Map 76*, Oil and Gas Inves. Ser., Sheet 2 (1947).

topographic front and the structured front is wider. Erosion has uncovered the Oriskany sandstone of the Lower Devonian along the axis of a prominent elongate dome for a distance of about 5 miles.

SUB-TRENTON

It is not exceptional to encounter showings of oil and gas and frequently considerable salt water in dolomitic sandstones and sandy dolomites at or near the unconformity at the base of the Black River limestone. Heretofore, the strata immediately below the unconformity in central Ohio have been called St. Peter sandstone, as it was thought that they occurred at a definite horizon that could be correlated with the St. Peter sandstone of the Upper Mississippi Valley.

The writer has observed that the so-called St. Peter sandstone of Ohio varies considerably in lithologic character from place to place, ranging from dolomitic sandstone to almost pure, finely crystalline dolomite. The latter is frequently mistaken for sand by the drillers. It has also been found that the strata immediately below the unconformity are not of the same age in all wells, but become younger southward in central Ohio.

A small amount of oil has been obtained from sandy zones in what is believed to be the Trempealeau formation at four localities in Ohio, namely, at Tiffin (No. 30 on map, Figure 1), in Seneca County; at Caledonia, No. 31, in Marion County; at Pickerington, No. 32, in Fairfield County; and at Newark, No. 27, in Licking County. In the vicinity of Tiffin, three wells produced oil, the best one of which had an initial production of 500 barrels daily, but soon declined to about 25 barrels. At Caledonia, four producing wells were drilled in 1918, which had initial productions ranging from 15 to 745 barrels of oil per day. At Pickerington a well drilled in 1920 found 10 feet of "pay sand" which produced about 8 barrels of oil daily.[50] At Newark about eight wells were drilled in 1924 and 1925 with initial open flows ranging from 85,000 to 250,000 cubic feet of gas per day and some oil. One well averaged 65 barrels of oil per day for 11 days. In Pittsfield Township, No. 6, Lorain County, a well drilled in 1946 had a settled production of 66,000 cubic feet of gas per day from a silty dolomite bed, 20 feet below the unconformity.

Of 67 available records of wells that penetrated strata below the Black River in central Ohio, 27 reported showings of oil and gas, some accompanied by salt water, a short distance below the unconformity, less than 40 feet. Of those that were drilled appreciable distances below the unconformity, very few reported any additional showings of oil or gas. Salt water, on the other hand, has been encountered, commonly in considerable volumes, even as deep as the Mt. Simon sandstone.

As most oil and gas showings reported from the Upper Cambrian rocks in central Ohio occur close to the unconformity and as, in most instances, only

[50] L. S. Panyity, "Oil and Gas Bearing Horizons of the Ordovician System in Ohio," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5 (1921), pp. 609–19.

salt water has been found at greater depths, it seems possible that there has been some updip migration of oil and gas along porous and permeable members which has been trapped beneath the unconformity. This suggests the possibility that there may be places where porous and permeable layers of sufficient thickness and areal extent occur in these rocks to have permitted the accumulation of pools of significant size where local structural conditions were favorable. The number of sub-Trenton wells in central and northeastern Ohio, northwestern Pennsylvania, and western New York is relatively small for the area involved.

Showings of gas have been encountered in the Little Falls dolomite in a well in Herkimer County and one in Madison County, New York, and in the Potsdam sandstone in a well in Oswego County. These occurrences are on the southwest side of the Adirondack Mountains.

The possibilities of the sub-Trenton rocks beneath the stronger anticlines in the eastern part of the Appalachian basin are intriguing. The great depth, however, probably precludes their early exploration. As has been pointed out, the hiatus at the unconformity beneath the Black River in the Hockenberry well, No. 20, is represented by approximately 4500 feet of strata, mostly dolomites and limestones, 120 miles east in the vicinity of Bellefonte. The disappearance westward of these strata is due partly to non-deposition and partly to truncation by the unconformity.